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-FINAL REPORT-

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~~FOR ARPA CONTRACT H0210035~~

REVIEW AND CRITICAL ANALYSES OF THE STATE-OF-THE-ART IN UNDERGROUND WORKS CONSTRUCTION

SPONSORED BY:
ADVANCED RESEARCH PROJECTS AGENCY
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FOUNDATION SCIENCES, INC

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Foundation Sciences, Inc.

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State of the Art Review of Underground Works in Oregon and Washington

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FINAL REPORT
for ARPA Contract HO210035
Review and Critical Analysis of the State-of-the-Art
In Underground Works Construction

FOUNDATION SCIENCES, INC.
Portland, Oregon
February, 1972

FINAL REPORT

Review and Critical Analysis of the State-of-the-Art In Underground Works Constructi[illegible]

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SUMMARY

Under the Advanced Research Projects Agency (ARPA) Contract Number HO210035, Foundation Sciences, Inc. has determined the feasibility of collecting information on the construction of underground works, especially those within the last twenty years. The gathering and quantitizing of this type of information has been performed for the Oregon and Washington areas as a pilot project.

The first phase of the study included the collection of the available data about the geology, design, construction and performance of existing underground rock excavations plus the tabulation of this knowledge for a data bank. To date, all information contained in the "general data" forms for 256 projects have been entered into the computer.

Four general computer programs were employed to obtain accurate answers to specific inquiries and report writing demands. The Inquire and Print program is the only program necessary for the data user and is available to all terminal users at any location in the United States. Detailed operating instructions are included for this program plus a brief discussion of three other programs used to enter the information into the computer.

SUMMARY

Under the Advanced Research Projects Agency (ARPA) Contract Number HO210035, Foundation Sciences, Inc. has determined the feasibility of collecting information on the construction of underground works, especially those within the last twenty years. The gathering and quantitizing of this type of information has been performed for the Oregon and Washington areas as a pilot project.

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The second phase of the study concentrated on the evaluation of data available with special reference to those items of design and construction affecting supports. Two projects of special interest were selected for intensive study, during a review of all tunneling data, by the project officer and principal investigator.

A more intense effort was made to obtain detailed information concerning these projects. Several visits to the owner's archives were made on each project as well as interviews with some of the key personnel involved in the design, construction, inspection and management of projects. Printed documents were microfilmed and the general projects were discussed with emphasis on interesting developments in each project. Using the advantage of hindsight, an attempt was made to obtain an overview of the entire project and see how well the separate phases of exploration, design, construction and inspection blended in order to form a finished project. Additional and separate calculations were performed by Foundation Sciences, Inc. to emphasize a specific point. Finally, procedures are recommended to improve future data collection of this type. Some of the important conclusions reached in this study are as follows.

1. Computer filing retrieval and selected analyses of tunnel data is feasible and desireable.

2. Most tunnel support systems are presently designed by rule-of-thumb or past-experience methods, and in many instances, engineers abrogate their tunnel support design responsibilities to the Contractor.

3. Geologic information is essential to the design and construction of tunnel supports. Generally, it is not collected or seldom used when it is collected.

4. A complete list of conclusions is contained on pages 2 through 5 of this report.

FINAL REPORT
for ARPA Contract HO210035
Review and Critical Analysis of the State-of-the-Art
In Underground Works Construction

Introduction

During the construction of underground works, especially those of the last twenty years, a large amount of experience has been gained and data generated. Unfortunately, very little of this knowledge has ever been organized, evaluated, and made readily available for the improvement of the industry. Under this contract, Foundation Sciences, Inc. has determined the feasibility of collecting this information, quantitizing it, and making it available as an experience bank. The gathering and quantitizing of this type of information has been performed on a small scale in the Washington and Oregon areas as a pilot project. As an additional phase of the work, two selected underground projects have been subjected to a detailed evaluation of major parameters affecting the work in general, and ground support in particular.

The basic objectives of the work were to:

1. summarize available experience in underground works,

2. isolate those factors which have had the greatest

influence on ground support, construction, economy, safety, and performance,

3. determine if generally applicable and useful relationships or rules can be established for underground support, excavation procedures, layout and design methods,

4. critically review existing projects where known problems occurred so future mistakes can be avoided.

5. point out the most potentially fruitful research areas for the development of improved excavation and support methods,

6. produce a microfilm and computer-controlled data bank on significant underground excavations.

One of the basic difficulties of a study such as this was the manipulation of an enormous mass of raw data. Some of the data was handled by computers and the work was organized in phases to permit periodic review of the results and their worth.

General Conclusions

1. Significant amounts of data are available on general tunnel practice.

2. The data is poorly organized and time consuming to retrieve.

3. Most of the useful data on physical properties has

been generated only in the last few years.

4. Storage and retrieval of specific information in a large timesharing computer bank is practical.

5. Access to the information requires small financial outlays to the potential user.

6. Many colleges, government organizations, and private business firms already have the necessary access equipment.

7. Nationwide access to the data file can be made available.

8. Very little useful data is available for design of support systems.

9. The state-of-the-art in tunnel design, especially support design, is non-existent in the highway tunnels, railroad tunnels and diversion tunnels examined under this contract. In these types of tunnels, "design" has been ultra conservative, having estimated safety factors as high as ten in many instances.

10. The advance in the state-of-the-art has occurred mostly in large underground openings such as powerhouses.

11. An estimated less than one percent of the projects studied used design methods developed after 1960.

12. Project construction and support installation details presently exceed the ability to mathematically model or theoretically analyze economically.

The general recommendations for future research projects are as follows.

1. All tunnels in the United States should be listed in a national general data file.

2. All tunnels in the United States, completed after January 1, 1960, should also be contained in a nationwide exploration, design and construction file.

3. Only selected projects of great interest in exploration, design, construction or maintenance problems should be studied in detailed case histories.

4. A system of data recording and retrieval should be instituted so that the same uniformly described results can be tabulated.

Conclusions and Comments Applicable to Ground Support for Undergound Excavation --

1. In general, tunnel design practice has little relationship to the potential within the present state-of-the-art. Therefore past practice can contribute little of a positive nature to the improvement of future support systems.

2. Almost all current support design is based on past experience and intuition. The result is excessively large safety factors, unnecessary costs and a continuation of existing methods.

3. Construction personnel are generally allowed too much control over support selection. In may instances additional support not only means an ultra-safe opening, but additional cost to the owner.

4. The principal rock load direction in support selection is often assumed to be vertical. Experience has shown that only in rare cases is the principal stress vertical in hard rock situations and very often it intersects the opening at a very flat angle. This fact is of extreme importance in tunnel design.

5. Little or no use is made of exploration techniques which are capable of producing design parameters necessary for more realistic analysis.

PHASE I WORK

The aim of the first phase of the Advanced Research Projects Agency (ARPA) Contract No. HO210035, was the collection of as much of the data as available about the geology, design, construction and performance of existing underground rock excavations and the tabulation of this knowledge for a data bank.

The program proceeded through the following steps to accomplish the goal of Phase I.

1. a search of published information on underground projects,

2. a canvas of those agencies in Oregon and Washington who had engaged in underground works in rock,

3. follow-up visits by project personnel to the officies of the most promising sources of information to enlist their support and to gather available data,

4. preparation and utilization of the necessary computer programs to compile and evaluate these data.

As required by the Contract, contact was made with two Department of Defense-sponsored Information Analysis Centers to help guide specific aspects of the research and to avoid duplication of previously published work. The United States Defense Atomic Support Agency Data Center (DASA) advised that no other projects have been completed or are now in progress that duplicates the present work. However, the reply from Oak Ridge National Laboratory included a listing of railroad tunnels

which they had identified as part of a civil defense study; the list of tunnels was added to the computer data bank.

Data Collection

As the first step in the survey of potential data sources, a form letter and questionnaire (see the Appendix) soliciting cooperation and data from various organizations which may have built tunnels or other underground caverns was sent to forty-four offices, broken down as follows:

A.	Federal, State and County Offices	6
B.	Private, Municipal and Public Utility Districts	26
C.	Highway Departments, Railroads	5
D.	Irrigation Districts	7
	Total	44

The reply of the agencies contacted by the initial contact letter (see the Appendix) included thirty responses, eighteen of which indicated projects of value to the study. From the eighteen agencies with projects of possible value, a listing of 140 tunnels and 1 underground powerhouse was received; the breakdown follows:

		Responses	Tunnels
A.	Federal, State and County Offices	6 of 6	63
B.	Private, Municipal and Public Utility Districts	17 of 26	30
C.	Highway Departments, Railroads	3 of 5	47
D.	Irrigation Districts	4 of 7	0
	Totals	30 of 44	140

At this stage of preliminary data gathering, more difficulty in receiving project information was experienced than was originally anticipated. The problem generally resulted from the large mass of unclassified information available about a project, and not from an agency's reluctance to make the information available. It was difficult for them to decide what information to select. Consequently, an additional contact letter was sent (see the Appendix) and a series of personal visits to owner's offices was begun to select pertinent data for the files.

Personal visits were made to 9 agencies, including Southern Pacific Railroad Company, Bechtel Corporation, the North Pacific Division of the Corps of Engineers, the Portland Water Bureau, the Portland District of the Corps of Engineers, Eugene Water and Electric Board, Seattle City Light, Burlington Northern Railroad Company and the Oregon State Highway Department.

The additional contact letter was mailed to eleven organizations who indicated, in their questionnaire reply, construction of structures of sufficient size and interest to be included in the detailed analysis of the study. In this contact letter these organizations were asked to make available, or to give the location of Design Memoranda, Bidding Documents, Completion Reports, Inspection or Performance Reports and Construction Daily Shift Reports

Through the personal visits and contact letters, a total of forty-five firms and agencies were contacted and 242 significant projects located. General data on 256 projects have been filed in the computer (see the Appendix).

Throughout the process of data collection, the gathered information varied greatly in completeness and in quality. In many cases the required information is available, but is not easily accessible. As a result, continuing personal visits were made to project owners' offices to search their dead files for pertinent information.

<u>Organization and Computerization of Data</u>

Preliminary data were accumulated by several different methods. Many of the tunnel information documents were duplicate copies which the project owners were willing to release permanently. However, a large portion of the currently tabulated data was either utilized on a loan basis or, at the owner's request, remained in the project office.

Due to the above-mentioned circumstances and the large accumulation of data, it was decided to employ a microfilm data retrieval system. Microfilm equipment, which includes a Starfile camera and a reader-printer, was utilized to record all documents which were not already on file in hard copy. Filming was done on 16-millimeter roll film, which may be easily converted to a computer-indexed aperture card system.

In the computer-indexed system, each of the various pieces of microfilmed data is given a unique file number which identifies the project, the type of data, and the page number. These numbers are then placed in the computer file bank. In an individual search for information on a certain project, or for a specific question, the computer can be questioned as to the availability of the data. The computer will then be able to respond with the microfilm file number. By reference to the file number, copies of the document can then be obtained upon request to the control agency.

Formulation of computer data sheets begin data organization for rapid access by the use of computer storage and retrieval. Four data forms were designed: general data, exploration data, construction data, and design data (see the Appendix). Data forms could be designed as well for inspection, maintenance, operation, cost or any other subjects of interest. The forms are designed to minimize judgment decisions during form completion so that non-technical personnel may be utilized to gather the data.

The General Data form lists twelve items of general interest and is established primarily to maintain control on incoming data and to demonstrate the workability of the system on the other more complicated files. The data files are designed for computer access which utilizes a

a teletype terminal and Omnitec phone couplet to a local interchange with the computer located in Seattle, Washington. All programs have been developed under the guidelines of a simplified programming language; and, because knowledge of computer programming is not a prerequisite for operation and program development, general office personnel have demonstrated their ability to successfully manipulate the data.

Computer Programs

All information contained in the General Data form has been entered into the computer. In order to maintain up-to-date computer files enabling the user to obtain accurate answers to specific inquiries and report writing demands, four general computer programs are employed.

1. File Maintenance Program - performs the functions of file creation and maintenance.

2. Inquire and Print Program - is designed specifically for applications that range from the quick extraction of specific data to the preparation of detailed printed reports.

3. Transaction Update Program - aids the control agency in updating master files and performs deletion, addition, and change operations.

4. Sort and Merge Program - enables the control agency to define and execute sort, merge, and file copying functions.

The data file, in order to be manipulated by any of the four general programs, must have a particular structure for efficient operation. The file structure for the General Data form (see the Appendix) illustrates how

a 12-field record can be organized. Each "record" of the file, which is represented by one line on the table, describes a single project. Twelve data fields comprise the record; each column in the figure represents a "field". The requirements of the general programs are that every record in a given data file must contain the same number of fields, arranged in the same order. Information has been supplied for each of the twelve data fields on 256 tunneling projects. These data have been entered into the computer as illustrated by the computer printout (see the Appendix).

The Inquire and Print program is the only program necessary for the data user and is available to all terminal users at any location in the United States. Through the use of basic computer commands (see the Appendix) and the Inquire and Print routine, the tunnel information held in the data bank may be manipulated to answer specific inquiry problems. For this reason detailed instructions for the operation of the Inquire and Print program are included in this report. A brief discussion of the other three programs follows the Inquire and Print operation instructions. This discussion describes, in a general manner, how the information contained in the General Data form was entered into the computer.

INQUIRE AND PRINT PROGRAM - The Inquire and Print program operates on one specific data file at a time; i.e., the General Data file. A

data file consists of data records, each of which contains a maximum of 100 fields of information. Each field in a given data record contains either alphabetic or numeric information. Whether a field has alphabetic or numeric characters dictates how the information in the field is to be processed in subsequent programs.

When the user defines his specific inquiry problem, he is ready to use the Inquire and Print program. The program operates on a data file to perform the following functions:

1. select all or some of the data records from the files,
2. take field totals on any numeric field in the selected records,
3. print all or some of the selected records or alternatively transfer control to user-supplied routines for printing and additional calculations.

To process the data file, the user must supply the Inquire and Print program with control information which describes the data records of his files and the work to be done. The Inquire and Print program may be executed by entering the necessary control information from a previously created control file or by responding to specific questions which are asked by the computer during the initial operation of the Inquire and Print program.

For each Inquire and Print run, the user must indicate which method of supplying control information is to be used. He does this by entering a FILES statement as soon as the Inquire and Print program is loaded. The

format of this statement is:

> <u>89 FILES, cntl, input</u>
>
> where the lower case words indicate portions of the statement that the user supplies:
>
> "cntl" is the name of the control file containing the control information. If the control information is to be entered by the total prompting method (no control file used), the name PROMPT or the symbol # should be used.
>
> "input" is the name of the data file to be processed.

If the user does not enter the 89 FILES statement the computer will ask for the names of those files before continuing.

<u>Control Information</u> - Whether the control information is entered into the Inquire and Print program by the control files, control statements (prompting), or a combination of the two, it must contain four types of information.

1. Record structure - the number of fields in each record of the data file, and whether each is alphabetic or numeric.
2. Field totals - the numeric fields on which field totals are to be taken.
3. Record selection - the criteria for selecting records for printing.
4. Printing instructions - the method to be used for printing the selected records.

Prompting - If no control file is used, the Inquire and Print program prompts the user for the four types of control information. By responding to the questions of the Inquire and Print program, the user directly supplies the necessary information and controls the operation of the Inquire and Print program.

Record Structure Specification - In order to read the records in the input file, the Inquire and Print program must know the structure of the record, including the number of fields it contains and whether each field is numeric or alphabetic. This information is constant with each file and can be provided to the user in table form.

The Inquire and Print program prompts for the record structure specification by requesting the user to enter the total number of fields in a record. The following message appears:

TOTAL NUMBER OF FIELDS IN A RECORD?

The user enters the number of fields immediately after the question mark; his answer is followed by a carriage return, R. The system then responds with:

ENTER N FOR NUMERIC FIELDS, A FOR ALPHABETIC FIELDS

n_1 TO n_2

where n_1 and n_2 are the beginning and ending field numbers for which the Inquire and Print program needs specification.

The user enters N or A for each field in the specified range (n_1 to n_2) which is set up in groups of five or fewer. The entries are made on the line following the question mark; consecutive entries are separated by a comma or a blank. If only one field remains, the message will be:

FIELD n_1
?

In the case of the General Data file, there are twelve fields with field 1 as numeric, fields 2 through 5 alphabetic, field 6 numeric, field 7 alphabetic, fields 8 through 10 numeric, and fields 11 through 12 alphabetic. The following is an example of the user computer exchange for this file.

Example 1
The control information for a sample record structure specification is given below (underlining indicates user response): Total Number of Fields in A Record? 12 (R) Enter N for Numeric Field, A for Alphabetic Fields 1 to 5 ? N,A,A,A,A (R) Fields 6 to 10 ? N,A,N,N,N (R) Fields 11 to 12 ? A, A (R)

Field Totals Specifications - As the Inquire and Print program selects records for printing, totals may be accumulated for any or all numeric fields in the selected records. The user has the option of selecting the numeric fields on which he wished to accumulate totals. The Inquire and Print program prompts the user for the field totals specification by asking him if the field totals are to be taken. The user responds to:

FIELD TOTALS?

with YES or NO. If he answers NO, no field totals will be taken. If he answers YES, a series of question marks are written. After each question mark, the user enters the field number of a numeric field to be totaled; only one field number may be entered after each question mark. The user enters zero (0) to indicate that all the desired field numbers have been entered.

Example 2
Field Totals? YES (R) ? 8 (R) ? 10 (R) ? 0 (R) In this example, field totals are to be accumulated on fields 8 and 10. Note the entry of 0 to end the input of field numbers.

Record Selection Specification - The user specifies the criteria which govern the record selection. The selection of a record is determined by comparing the value of one of its fields with a test value supplied by the user. Selection criteria can be composed of up to 100 different "and/or" statements chosen from the following list of logical operators.

1. EQ - Field value equals test value.
2. NE - Field value does not equal test value.
3. LT - Field value is less than test value.
4. GT - Field value is greater than test value.
5. LE - Field value is less than or equal to test value.
6. GE - Field value is greater than or equal to test value.

It is possible to specify multiple relational tests in which the contents of several fields of a record are compared with specified test values. These multiple relational tests, called "logical groups", specify both AND or OR conditions. In an OR condition, a record is selected if any one of the relational tests is passed. In an AND condition, a record is selected only if each of the relational tests connected by the AND relation are passed.

In building the selection criteria for the selection of records, there are certain rules to follow. These rules apply particularly to the formation of multiple logical groups:

"IF" is the word used for the logical OR when multiple logical groups or tests are involved. "AND" is the word for the logical AND.

Example 3
If field 3 equals "CORPS OF ENGINEERS". If field 9 equals 15. In logical terms, these two tests mean that if either field 3 equals "CORPS OF ENGINEERS" or field 9 equals 15, select the record. -- If field 3 equals "CORPS OF ENGINEERS" and field 9 equals 15. This logical groups means only if field 3 equals "CORPS OF ENGINEERS" and field 9 equals 15, select the record.

"IF" must start each selection criterion. Each selection criterion is called a "logical OR group".

Example 4
If field 6 equals 1945 And field 7 does not equal "HORSESHOE" And field 3 does not equal "CORPS OF ENGINEERS" } Logical OR group If field 9 equals 15 And field 8 is less than 1500 } Logical OR group This example shows two "logical OR groups" linked together to make up two selection criteria. A record is selected if field 6 equals 1945 and field 7 is not equal to "HORSESHOE" and field

3 is not equal to "CORPS OF ENGINEERS", <u>or</u> if field 9 equals 15 and field 8 is less than 1500.

If any "logical OR groups" develop a true condition, the record will be selected.

Example 5	
If field 10 is greater than or equal to 0	
Any record with the value of field 10 greater than or equal to zero will be selected.	
If field 6 equals 1930 And field 11 equals "RAILROAD"	} Logical OR group
If field 9 is greater than or equal to 0	} Logical OR group
Any record with either field 6 equal to 1930 and field 11 equal to RAILROAD, <u>or</u> field 9 greater than or equal to 0 will be selected. The same rule would apply if there were more than two logical OR groups; if any one group developed a true condition, the record would be selected.	
Each record in the file is compared with the record selection criteria. A record is compared with each logical OR group (in the order it is specified) until it meets a true condition; it is then selected and the next record is compared. If a record does not satisfy any logical group in the criterion, it is not selected.	

The Inquire and Print program prompts the user for the record selection specifications by asking him if he wished to enter selection criteria:

SELECTION CRITERIA?

The user responds YES or NO. A response of NO causes all records to be selected. If the response is YES, the Inquire and Print program prints a series of question marks; after each question mark the user enters part of his selection criteria. His selection can contain up to 100 relational tests.

A criterion consisting of a single relational test is entered as:

?IF, field number, relational operator (R)

? test value (R)

Each relational test in the selection criteria is entered on two lines following the question marks.

To indicate the end of the selection criteria the user types:

?END, number, word

where "number" is any numeric value and "word" is any alphabetic string following the question mark. Thus, if the record selection specification contains a single relational test, it is entered as:

?IF, field number, relational operator (R)

? test value (R)

?END, number, word (R)

Example 6
Select records if the name appearing in field 3 is equal to "CORPS OF ENGINEERS".

Selection Criteria ? YES (R)
? IF,5,EQ (R)
? "CORPS OF ENGINEERS" (R)
? END,0,END (R)

If an alphabetic string contains blanks or commas, the string must be enclosed in quotes when it is entered.

For multiple relational tests, the format of the selection criteria is:

Example 7

Select records if the value of field 8 is greater than 0 and less than 9000,or if the value of field 8 is less than 0 and the value of field 9 is greater than 0, or if the value of field 9 is equal to 0.

Selection Criteria ? YES (R)	
? IF,8,GT (R) ? 0 R ? AND,8,LT (R) ? 9000 R	First logical OR group
? IF,8,LT (R) ? 0 R ? IF,9,GT (R) ? 0 R	Second logical OR group
? IF,9,EQ (R) ? 0 R	Third logical OR group
? END,0,END (R)	End of selection criteria

In the above example a record is selected if it satisfies any one of the logical OR groups.

Printing Instruction Specification - Three printing options are provided by the Inquire and Print program. By the first option

every field of the selected record will be printed. By the second option, only the fields of the selected records in the order specified by the user will be printed. By the third option, the user can specify the format in which the selected records are to be printed, including column headings and explanatory remarks. The third option also allows the user the opportunity to perform computations with the data and print the results.

If the user selects the first or second option, he has the choice of whether the fields are to be printed in packed-zone or in full-zone format. If the user chooses the packed-zone format, the fields printed out will be joined together; no spacing is provided between consecutive fields. A numeric value printed under this format does have a trailing blank character and may have a preceding space; no plus sign (+) is printed. However, if the value is negative, there is no space; a minus sign (-) is printed. By the full-zone format, the fields are zone aligned. Each zone contains 15 character positions (columns), and every fifteenth column is the start of a new zone. By this format, the field values can be printed in a neat, readable form. Any numeric field can be contained in a 15-column zone; blanks are printed following the number to fill the zone. For alphabetic fields, any field containing 15 characters or less can be printed in one zone. However, if the field contains more than 15 characters, the field value will occupy two consecutive zones; the column alignment may be affected.

Examples of a packed-zone and a full-zone printout are as follows:

<u>Packed Zone</u> Blue River Dam1795 Circular Mud Mountain1991 Circular <u>Full Zone</u> Blue River Dam 1795   Circular Mud Mountain 1991   Circular

The Inquire and Print program prompts for printing instruction specification by asking the user if he wishes to print the entire selected record. The user responds to:

PRINT ENTIRE RECORD?

If the user responds with YES, the program will then type:

PACK OR FULL ZONE PRINT?

The user enters PACK for packed zone format; he enters either FULL or ZONE for full zone format.

If the user responds with NO, to the question, "PRINT ENTIRE RECORD?", then the Inquire and Print program types:

LIST FIELDS IN SEQUENCE
?

The user responds by indicating whether he wants the program to use his

his own inserted print routines or to print only specified fields. If he wishes to use his print routine or if he wishes no printing at all, he enters 102 after the question mark. If he wants only certain fields of the selected records printed, he enters the field number of the first field to be printed. The Inquire and Print program then prints a series of question marks, and the user responds to each with a field number. The field values will be printed, left to right, in the order in which their field numbers are specified. To end the field sequence specification, the user types zero (0). The Inquire and Print program then responds:

PACK OR FULL ZONE PRINT?

The user enters PACK for packed zone printing of the fields; he enters FULL or ZONE for full zone printing.

Example 8

Print only the first, second, and tenth fields of selected records using packed zone printing.

```
Print Entire Record?  NO (R)

List Fields in Sequence
? 1 (R)
? 2 (R)
? 8 (R)
? 10 (R)
? 0 (R)

Pack or Full Zone Print?  PACK (R)
```

Control File Program - This program builds a control file for use in an Inquire and Print program run. The use of a pre-constructed control file would save time where the same or similar type search of the files was frequently performed. The control file may contain all or part of the required control information. The user creates the control file by answering specific questions asked by the Control File program. These questions are essentially the same questions asked by the Inquire and Print program in the fully prompted mode. If the user wishes to enter all of the control information through the control file, his responses to the Control File program questions are identical to his responses to the Inquire and Print program questions. However, if he wishes some prompting during the execution, his responses to the Control File questions are different; these responses are described in the following paragraphs.

To prepare the program for a run, the user must first load the Control File processor into his work area and then enter a FILES statement in the following form:

89 FILES cntl

where:

"cntl" is the name of the control file to be created.

The FILES statement is followed by a RUN command and the Control File program begins operating. If the 89 FILES statement is omitted

by the user the computer will ask for the name of the control file. The questions generated and the user's responses (for prompting by the Inquire and Print program) are as follows:

The first question asked by the Control File program is:

RUN TYPE?

For a control file to be used with the Inquire and Print program, the user must enter INQUIRY after the question mark.

Record Structure Specification - The user must enter the record structure for the data file to be processed by the Inquire and Print program. The user cannot request prompting by the Inquire and Print program for this control information; it must be entered during the execution of the Control File program. This information is the same as the record structure information explained earlier under the Inquire and Print program.

Field Totals Specification - If the user wishes to be prompted in the Inquire and Print program he responds with YES. The Control File program then types a question mark on the next line and the user enters a zero (0). If the user wishes to have specific fields totaled, he types YES and the numbers of those fields; otherwise, he types NO.

Record Selection Specification - The Control File program types:

SELECTION CRITERIA?

to be prompted by the Inquire and Print program, the user enters YES and a carriage return (R). The Control File program then responds with a question mark and the user enters: END, number, word - where number is any numeric value and word is any character string. If the user has specific selection criteria these are entered in the same manner as explained under the Inquire and Print program.

Example 9
Selection Criteria? <u>YES</u> (R) ? <u>END,0,END</u> (R) These responses cause the Inquire and Print program to prompt the user for the record selection specification.

Printing Instruction Specification - For the printing instruction information, the Control File program types:

PRINT ENTIRE RECORD?

If YES is typed, the whole record will be typed. To be prompted, or to select specific criteria in the Inquire and Print program, the user enters a NO and the Control File program types:

LIST FIELDS IN SEQUENCE
?

If the user wishes to list fields he does so in the same manner described

earlier under the Inquire and Print program. If he wishes to be prompted the user enters a zero (0) after the question mark.

The control file created as described above and used by the Inquire and Print program is an external (symbolic) file. Thus, it is possible for the user to construct his control files from the terminal without using the Control File program.

Terminal Control File Construction - In the symbolic control file, a line number precedes each group of data in the file. These data represent the control information; and must always appear in the following order:

1. record structure specification,
2. field totals specification,
3. record selection specification,
4. printing instruction specification.

If the user chooses to construct his own control file, he enters a line number "n" followed by a logical grouping of the control information. "n" can be any number from 1 to 99999. Successive line numbers and data are entered until the required control specifications nave been supplied. The user then assigns the file a name and saves the file; it can then be used with the Inquire and Print program at any time.

Record Structure Specification - The record structure specification must always be the first control information contained

in the control file. This information is entered in the form:

$c, s_1, s_2, \ldots, s_c$

where:

"c" is the number of fields in each record.

"s" is a code representing either a numeric or alphabetic field. "s" is 0 if the field is numeric; it is 1 if the field is alphabetic. The user must enter the appropriate code for each field in a record. There must be exactly "c" entries.

Example 10

```
1000  12
1010  0,1,1,1,1,0,1,0,0,0,1
```

or

```
1000  12,0,1,1,1,1,0,1,0,0,0,1,1
```

Both of the examples are record structure specifications for a record containing 12 fields, the first numeric, the next four alphabetic, the sixth numeric, the seventh alphabetic, the next three numeric and the last two alphabetic. Note that in this case, there must be 12 ones or zeros following the count specification.

The user may enter zero (0) for the record structure specification. This will cause the Inquire and Print program to prompt the user for the control information.

Field Totals Specification - The field totals specification must follow the record structure specification in the control file.

If the user wishes to take field totals, he can specify this control information in his control file. It is entered as:

$c, f_1, f_2, \ldots, f_c$

where:

"c" is the number of fields to be totaled.

"$f_1, f_2, \ldots, f_c$" are the field numbers of the fields to be totaled. The user must enter exactly "c" field numbers.

Example 11	
1100 2	two fields to be totaled
1150 8 10	fields 8 and 10
or	
1100 2,8,10	

An entry of zero for the field totals specification in the control file causes the Inquire and Print program to prompt the user for the control statements. An entry of 101 indicates that no field totals are to be taken.

Example 12	
1100 0	specifies prompting for field totals specification
1100 101	specifies no field totals

Record Selection Specification - Record selection specification must always follow the field totals specification in the control file. If the user enters zero for this specification, he requests to be prompted for the control information by the Inquire and Print program. By entering 101, he indicates that no records are to be selected; all the records are to be printed.

Example 13	
1200 0	specifies prompting for record selection specification
1200 101	specifies selection of all records

If the record selection criteria are to be contained in the control file, the complete record selection specification must be generated as follows:

The number of "logical OR groups" in the criteria

The number of relational tests followed by the specification of the actual relational tests for each "logical OR group"

The relational test, which is the basic element of a record selection criterion, has the following format:

f,r,v

where:

"f" is the field number to be tested

"r" is the relational operator code number

"v" is the test value (numeric or alphabetic)

Following is a listing of allowable relational operators and the corresponding relational operator codes, "r":

r	Relational Operator
1	EQ
2	NE
3	LT
4	GE
5	GT
6	LE

To construct a "logical OR group" the user must first supply the number of relational tests in the OR group, then list the actual relational tests. The format for a "logical OR group" with more than one relational test is:

$$c, f_1, r_1, v_1, f_2, r_2, v_2, \ldots f_c, r_c, v_c$$

where "c" is the number of relational tests in the "logical OR group", "f_1" is the field number for the first relational test, "r_1" is the first relational operator code, and "v_1" is the first test value, "f_c, r_c, and v_c" correspond to the last field number, operator code, and test value in the OR group. The user must enter "c" relational tests.

If the selection criteria contain one or more "logical OR groups", the user must first supply the number of "logical OR groups" in the criteria followed by the OR groups, listed according to the format above. Thus, the selection criterion for one "logical OR group" must appear as:

$n, c, f_1, r_1, v_1, f_1, r_2, v_2, \ldots, f_c, r_c, v_c$

where "n" is the number of "logical OR groups" (n = 1), and c, f_1, r_1, etc., as defined in the preceeding paragraph. Multiple OR groups must appear in the control file as follows:

$n, c_1 \ldots, c_2 \ldots, c_3 \ldots, c_n$

where "n" is the count of "logical OR groups" in the criteria and "c_1, c_2, c_3, and c_n" are the first, second, third and last OR groups, respectively.

Example 14

If field 8 is not equal to 0

And field 9 is greater than 15

And field 3 is not equal to "CORPS OF ENGINEERS"

Or if field 6 is greater than 1900

Or if field 7 is equal to CIRCULAR

And field 11 is not equal to HIGHWAY

And field 10 is less than 1100000

1200 3	3 OR groups
1210 3	3 relational tests in group one
1220 8,2,0	If field 8 not equal to 0
1230 9,5,15	And if field 9 is greater than 15
1240 3,2,"Corps of Engineers"	And if field 3 not equal to Corp Engr.
1250 1	1 relational test in group two
1260 6,5,1900	If field 6 greater than 1900
1270 3	3 relational tests in group three
1280 7,1,Circular	If field 7 is equal to Circular

1290 11,2, Highway	And field 11 not equal to Highway
1300 10,3,1100000	And field 10 less than 1100000

or

1200 3,3,8,2,0,9,5,15,3,2,"Corps of Engineers"
1210 1,6,5,1900,3,7,1,Circular,11,2,Highway,10,3,1100000

Printing Instruction Specification - Printing instruction specification must always follow the record selection specification in the control file. The user has four printing options from which he may choose; he may request:

1. prompting from the Inquire and Print program,
2. use of his own inserted print routine,
3. printing of all fields in the selected records,
4. printing of only specified fields in the records.

If the user wants to be prompted, an entry of zero causes the Inquire and Print program to prompt for the print instructions. If the user enters the value 102, the Inquire and Print program turns control of printing over to user-supplied printing routines.

If the user enters the value 101, all of the fields of selected records will be printed just as if he had answered YES to the question "PRINT ENTIRE RECORD?" using control statements. The user must then specify whether packed-zone or full-zone printing of alphabetic fields is desired; to do this the user enters a 1 for full-zone printing or a 0

for packed-zone printing.

If the user wishes to print only certain fields of selected records, he must enter the following information for the printing specification in the control file:

$c, z, f_1, f_2, \ldots, f_c$

where:

"c" is the total number of fields to be printed.

"z" is 1 or 0 and specifies the zone printing format.

"$f_1, f_2, \ldots f_c$" are the actual numbers of the fields to be printed. There must be exactly c field numbers entered.

Example 15
Construct the control file in order to print the first, ninth, second, fifth, and thirteenth fields of selected records using full zone printing. Print the fields in the above order. <u>1400 5</u> <u>1410 1</u> <u>1420 1,9,2,5,12</u> or <u>1400 5,1,1,9,2,5,12</u>

<u>User Exits</u> - To enhance the data presentation capabilities, the Inquire and Print program allows the user to enter his own printing and processing routines. The user-coded routines may be inserted into the

Inquire and Print program at four user exits. The coded routines are coded in standard Basic computer language, and all the Basic commands can be used except "restore" or "backspace". All of the user exits become active during an Inquire and Print run. These exits are located at lines 4000-4999 (Exit 2); lines 5000-5999 (Exit 1); lines 6000-6999 (Exit 3); and lines 7000-7999 (Exit 4).

User Exit 1 is referenced after control information has been read and all the files have been opened. User Exit 1 is ideal for inserting routines which print titles and initial column headings.

User Exit 2 becomes available before each record is read. Because the Inquire and Print field totals are accumulative only on selected records, this exit may be used to accumulate totals on every record read.

User Exit 3 is given control each time a record is selected. All fields of the selected record, field totals (as specified in the control information), and record counts are available for use in the user-supplied routine. All totals and counts are current through the record just selected.

At this exit, the user can insert his own-code routine which may control the following types of processing:

1. printing fields of the record in any format and order,
2. causing spacing and column positioning,
3. performing intermediate calculations,
4. printing results of intermediate calculations.

This exit can also be used to count print lines and to print headers, when needed, for special fixed-page-length reports.

User Exit 4 becomes active after all records have been read. All final totals and record counts are available for use in user-supplied routines at this exit. Exit 4 can be used as a final processor to print final totals, the results of final calculations, and final messages. After control is returned from this exit the Inquire and Print program prints an end of run message which consists of field totals (if requested), record counts, and the message NOW AT END. If the user wished to have the end of run message eliminated, he could end his user-supplied routine at Exit 4 with a STOP or END statement.

It is the user's decision whether or not to take advantage of the user exits. If the user exits are utilized, the user should observe the following rules:

1. Each user-supplied routine inserted at Exit 1, Exit 2, or Exit 3 must end with a RETURN statement to return control to the Inquire and Print program.

2. The routine inserted at Exit 4 must contain a RETURN statement unless the option of eliminating the end of run message is used. In this case, the RETURN statement is replaced by the use of the STOP and END statement. The STOP and END statements should only be used at this exit.

3. The commands, RESTORE and BACKSPACE, should not be used in the user-coded routines. All other basic commands are acceptable.

4. Particular care must be taken in choosing the variable and array names to be coded in the user's routines. These names are described in the Appendix.

Variables and Arrays - Through user exits, the data are handled by the Inquire and Print program during execution is available to the user. These data are contained in variables and arrays. A list of the variables and arrays, which are made available to the user for his own-code routines, is shown in the Appendix.

User Exit Procedure - Once the user has decided to utilize the Inquire and Print user exit capabilities, he must observe the following procedure:

1. Enter his user-coded routines at the terminal. These routines must be entered prior to the execution of the Inquire and Print program and must be named (NAME command) and saved (SAVE command) in the user's computer library.

2. Load the Inquire and Print program into his work area by using a LOAD command.

3. Merge the user-supplied routines with the Inquire and Print program. The MERGE command is used to produce this result.

Examples of User-Coded Routines - The user wants to print a listing of all tunnel projects contained in the General Data file that are an appropriate heading for the report, a listing of project name, shape, and cost for each project. In addition, he would like to know the average cost per linear foot for both arched roof and circular shaped tunnels.

Three user exits will be used in the above described program (5000-5999, 6000-6999, and 7000-7999). The user will specify his selection criteria based on field 8 (tunnel length - tunnels with a length greater than 500 feet), and on field 9 (tunnel diameter or span - tunnels with a span greater than 15 feet). Following is a sample of the user-inserted coding at the three user exits required to perform the desired function.

Print Heading - User Exit 1

```
5000 Print"   This Program Selects Specific Tunnels Over 500 Feet"
5010 Print"   In Length Having Spans Greater Than 15 Feet and Cal-"
5020 Print"   culates Their Cost Per Linear Foot and Finds the"
5030 Print"   Average Cost For Each Type Of Tunnel Selected."
5040 Print
5050 Print Using 5060
5060 (15 spaces) Name (21 spaces) Shape (18 spaces) Cost
5070 Print
5080 Return
```

Lines 5000-5030 print the desired title heading. Lines 5050 and 5060 print the appropriate column headings. Lines 5040 and 5070 skip lines between printing. Line 5080 is necessary to return control to the Inquire and Print program

Print Selected Records - User Exit 3

```
6000  X1 = A (10)/A(8)
```

```
6010  IF A(7)$EQ "Circular" GOTO 6050
6020  X2 = X2 + 1
6030  Z1 = Z1 + 1
6040  GOTO 6070
6050  X3 = X3 + X1
6060  Z2 = Z2 +1
6070  Print Using 6080, A(2)$, A(7)$ , A(10)
6080: ################## (10 sps) ##################(15 sps) ####
6090  Return
```

Line 6000 divides the cost by the length of each tunnel. Line 6010 checks to see if A$(7) is equal to Circular (A$(7) holds the contents of field 7 in the currently selected record). Field 7 contains the shape of the tunnel; a shape equal to circular identifies a particular tunnel. Line 6030 counts the number of arched roof shaped tunnels selected. Line 6040 gives control to line 6070 to print the currently selected record (a project with an arched roof shape). If the project had a circular shaped tunnel, line 6010 would have given control to line 6050 to total the cost per linear foot of circular tunnels and count the number of circular tunnels, (see lines 6020 and 6030). Line 6070 prints the name, shape, and cost for every selected record (selected if tunnels have an arched roof or ciruclar tunnel shape). Line 6080 is how the printing in line 6070 will be formatted. Line 6090 returns control to the Inquire and Print program.

Print Final Totals - User Exit 4

```
7000  X4 = X2/Z1
7010  X5 = X3/Z2
7020  Print
7030  Print
7040  Print
7050  Print Using 7060,Z1,X4
7060: Average Costs Per Linear Foot For ## Arched Roof Tunnels $#####
7070  Print Using 7080, Z2, X5
7080: Average Costs Per Linear Foot For ## Circular Tunnels $#####
7090  End
```

Line 7000 computes the average cost per linear foot of the arched roof tunnels; line 7010 computes the average cost per linear foot for circular tunnels (the totals were accumulated in User Exit 3). Line 7050 prints the number of arched roof tunnels and the average cost per linear foot. Lines 7060 and 7080 are how the printing will be formatted. Line 7090 ends execution of the Inquire and Print program. This statement is used to suppress the printing of the normal end of run messages.

The complete user-supplied routines would then look as follows:

```
5000  Print"    This Program Selects Specific Tunnels Over 500 Feet"
5010  Print"    In Length Having Spans Greater Than 15 Feet and Cal-"
5020  Print:    culated Their Cost Per Linear Foot And Finds The"
5030  Print:    Average Cost For Each Type Of Tunnel Selected."
5040  Print
5050  Print Using 5060
5060              Name              Shape              Cost
5070  Print
```

```
5080  Return
6000  X1 = A(10)/A(8)
6010  IF A(7)$EQ"Circular"GOTO 6050
6020  X2 = X2 + X1
6030  Z1 = Z1 + 1
6040  GOTO 6070
6050  X3 = X3 + X1
6060  Z2 = Z2 + 1
6070  Print Using 6080, A(2)$, A(7)$, A(10)
6080: ##################        ##################        #####
6090  Return
7000  X4 = X2/Z1
7010  X5 = X3/Z2
7020  Print
7030  Print
7040  Print
7050  Print Using 7060, Z1, X4
7060: Average Costs Per Linear Foot For ## Arched Roof Tunnels $#####
7070  Print Using 7080, Z2, X5
7080: Average Costs Per Linear Foot For ## Circular Tunnels $#####
7090  End
```

This Program, when merged with the Inquire and Print program, produces the following results:

This Program Selects Specific Tunnels Over 500 Feet In Length Having Spans Greater Than 15 Feet and Calculates Their Cost Per Linear Foot and Finds The Average Cost For Each Type Of Tunnel Selected.

Name	Shape	Cost
Blue River Dam Div	Circular	316
Cougar Main Div	Arched Roof	167
Cougar Reg Outlet	Circular	355
Green Peter Div	Arched Roof	781

Big Cliff Div	Arched Roof	428
Knowles Creek	Arched Roof	431
Sunset	Arched Roof	177
Vista Ridge West	Arched Roof	4166
Vista Ridge East	Arched Roof	4352

Average Cost Per Linear Foot For 7 Arched Roof Tunnels $ 1500

Average Cost Per Linear Foot For 2 Circular Tunnels $ 335

The remaining programs, File Maintenance, Transaction Update, and Sort and Merge, are used basically by the control agency to process and update the various files. The explanation of these three programs will be very brief, as the user needs only to be aware of their general existence.

FILE MAINTENANCE PROGRAM - The file Maintenance program is designed to help the control agency perform the necessary creation and file maintenance tasks. As a generalized, file-oriented program, it can be executed under one of three options:

Create - permits the creation of a new data file.

Update - permits the updating of an existing data file through the deletion of records, the modification of fields of records and the addition of new records.

Copy - permits copying of records from one data file to another.

Data Files - The data files processed by the File Maintenance

program are internally formatted files; they contain fixed-length records of up to 100 fields. The fields are either numeric or alphabetic.

Control Information - Because the File Maintenance program is a generalized program, control information is necessary to direct the run operation. This information may be supplied either by "total prompting" or "control files" methods, or a combining of both into a "prompting/control file" method.

If the "total prompting" method is used, the control information is supplied during the exectuion of the File Maintenance program. When using the "control file" method, a file containing the control information is created and saved before executing the File Maintenance program. This control file, an external (symbolic) format, is constructed by using the same Control File program explained under Inquire and Print program.

When the control information for several File Maintenance program runs is similar but not identical, a combination "prompting/control file" method can be used. A control file that contains all of the control information that is constant for the File Maintenance program run is created, and prompting can be requested at execution time for any control information that varies.

For each File Maintenance program run, the method of supplying control information must be indicated. This identification is made in the FILES statement similar to the 89 FILES statement described earlier.

The following examples show the various file statements for the different options available.

• Create Option

Example 16

When making a CREATE run, a FILES statement must be used to designate the method of entering control information and the name assigned to the data file being created. The format of this FILES statement must be as follows:

89 FILES cntl, input, output, #

where the lower case words indicate portions of the statement that the user supplies:

"cntl" is the name of the control file containing control information. If the control information is to be entered by the total prompting method (no control file used), the name PROMPT or the symbol # should be used.

"input" is a temporary file name. Even though no input file is used during a CREATE run, the user must enter a name or the symbol # in this position of the statement.

"output" is the name assigned to the data file being created.

"#" is a symbol representing a temporary file used by the File Maintenance program. It may be omitted if the records to be added to the new file are contained in the control file, "cntl".

• Update Option

Example 17

Whenever a data file is processed for updating, the File Maintenance program constructs a new file which contains the undeleted records and their modifications, as well as the added records. A FILES

statement must be used in an UPDATE run to identify the file being processed and the new file being constructed. This FILES statement is also used to designate the user's method of entering control information. Its format must be as follows:

89 FILES cntl, input, output, #

where the lower case words indicate portions of the statement that the user supplies:

"cntl" is the name of the control file containing control information. If no control file is used, the name PROMPT or the symbol # should be used.

"input" is the name of the data file to be processed.

"output" is the name assigned to the new updated file. The user may designate the input file and output file to be the same ("input" and "output" are the same name). However, this is not recommended; if the user should make an error in specifying the conditions for deletions or modifications, he would no longer have a file containing his original data records after the UPDATE run.

"#" is a symbol representing a temporary file used by the File Maintenance program. It may be omitted if the records to be added to the update file are contained in a control file.

- Copy Option

Example 18

The COPY option of the File Maintenance program is used to copy records of one data file onto another data file. The FILES statement used is of the following format:

89 FILES cntl, input, output, #

where the lower case words indicate portions of the statement that the user supplies:

"cntl" is the name of the control file. If no control file is used, "cntl" is the name of a temporary file. In this case, the name PROMPT or the symbol "#" should be used.

"input" is the name of the file to be copied.

"output" is the name of the file created by the COPY operation.

"#" is optional. "#" is a symbol representing a temporary file.

User Exits - The File Maintenance program allows the user to enter his own processing routines if necessary, to handle the nonstandard file. The user-coded routines may be inserted in the File Maintenance program in two user exits located at lines 4000-4999 (Exit 2) and lines 5000-5999 (Exit 1).

Exit 1 becomes available after control information has been read and all the files have been opened. This exit is used when the data records of the input file are preceded by records. The routine inserted at this exit is used to read in the header label and to position the file at the first field of its first data record.

Exit 2 becomes available before each record is read. Special read routines can be inserted at this exit to read variable-length records. Exit 2 can also be used during the UPDATE option to take field totals on every record read. A routine to accumulate the totals, count how many records have been read, and print the field total results before the end of the file is encountered can be inserted.

TRANSACTION UPDATE - The Transaction Update program aids the control agency in updating master files and permits the use of one or two transaction files containing records to perform deletion, addition, and change operations. The program also permits the control agency to insert own-code routines in the program to fulfill unique processing requirements.

The Transaction Update program uses three types of files to update a master file:

1. An input master file that can be either an internal- or external- format file created and maintained by the File Maintenance program or the Transaction Update program.

2. A transaction file that can be either an internal- or external- format file created and maintained by the File Maintenance program or the Transaction Update program. Either one or two transaction files can be used to update a master file.

3. A control file that is an external-format file created by the Transaction Specifications program containing information describing the records in the input master file and in the transaction files. It also describes the specifications for the master file update by the Transaction Update program. The control file is created by running the Transaction Specifications program.

<u>Control Information</u> - The Transaction Update program is a general program and the control information must be supplied. The control information is supplied for each type of update to the Transaction Update program in the form of the control file created during the operation of Transaction Specifications. The Transaction Specifications program, which

operates in a fully prompted mode, builds the control file from the responses to questions asked during the run. A control file, which is in external (symbolic) format, contains all the information required to direct the Transaction Update program to use its transaction update capabilities.

User Exits - The transaction update program provides 10 user exits to allow the insertion of code routines to perform any of a variety of special processing functions that are beyond the normal scope of the Transaction Update program's generalized processing. All 10 exits, or any combination of the 10 can be used to provide the update capabilities required. All 10 of the user exits become active during a Transaction Update run. The exits are located as follows:

1	1000 through 1999	Before any files are opened
2	2000 through 2999	After the control file is read and stored
3	3000 through 3999	Before each record is read
4	4000 through 4999	After each record is read
5	5000 through 5999	After an out-of-sequence condition occurs on a transaction file
6	6000 through 6999	After a matching condition occurs prior to update
7	7000 through 7999	After each operation step of an addition or change transaction occurs

8	8000 through 8999	Before each output master record is written
9	9000 through 9999	After each output master record is written
10	10000 through 10999	After program processing is completed

The data processed during the execution of the Transaction Update program is available through the user exits.

SORT AND MERGE PROGRAM - The Sort and Merge program enables the control agency to define and execute sort, merge, and file copying functions. The Sort and Merge program contains four separate processors or sub-programs: CONTROL, SORT, MERGE, AND COPY. The CONTROL processor allows the specification of requirements for the SORT, MERGE or COPY processors in a conversational mode. The CONTROL processor then translates these requirements and stores them as specifications in a control file, which is assigned a name and saved for immediate or subsequent use.

The SORT processor permits the user to sort data files into any sequence. As many as 10 data files, in either symbolic or internal format, can be used as input to this processor. The output file from the SORT processor can be in either symbolic or internal format. Up to 25 data fields can be used to control the SORT. These sequence control fields, or sort keys, can be any combination of alphabetic/numeric characters,

in either ascending or descending sequence, or in both.

The MERGE processor allows the user to merge two or three data files, each in the same sequence, into one data file. Like the SORT processor, the MERGE processor can control as many as 25 fields in either ascending or descending sequence. The input file to the MERGE processor and the merged output data file can be in either symbolic or internal format.

The COPY processor enables the user to copy one file and create a second one. The processor does not require any sequence control fields. The input and output files can be in either symbolic or internal format. This processor can be used to rename internal or symbolic format files that are too large to load and name.

The Sort and Merge program can accept either symbolic or internal format files. If more than one file is input to the SORT or MERGE processors, the files can be of different formats. The output file from any of the processors can be in either symbolic or internal format and does not have to correspond to the input file format.

Computer Equipment

The equipment necessary to obtain access to the data bank is as follows:

1. standard teletype terminal,
2. standard telephone,
3. telephone computer coupler

The monthly rental on this equipment is under $90.00; however, there is a large variety of faster and more complex terminals available. The data bank may also be accessed directly by other in-house computers and those computers may, in turn, be used as a terminal.

The telephone connection in most large cities in the United States is to a local line. The total cost would be a minimum of about $120.00 per month including the charge for computer connection time which is based on actual time used. This charge should be well within the ability of numerous design firms, schools, contractors, government agencies and other interested parties throughout the country.

Personnel Training

The training necessary for the use of the data bank ranges from none to two days depending upon the individual's intelligence, past experience, and the complexity of the search and data manipulation. The average engineer or technical individual should be able to operate the program with just the aide of the operation manual and prompting by the computer. A few hours of explanation on the use of Basic computer language will allow complete utilization of the more complex options available in the user exit capacity of the program.

PHASE II WORK

Preliminary Analysis of Data

The second phase of the ARPA contract was the intensive study of two selected case histories of special interest in the Oregon and Washington areas. This study was intended to provide a detailed analysis of the records of a particular project and determine the methods of exploration, design and construction, and to determine whether these methods produced the desired results. This portion of the program was intended to highlight the use of any exceptional methods, to indicate where better methods could have been used and to determine if full advantage was taken of available data and technology.

In order to obtain a list of prospective tunnels for the pilot project, the original data list was searched by the computer for all the underground projects which fulfilled the requirements of this portion of the study: all tunnels were to have been completed after 1950; the diameter was to be 15 feet or greater; and analysis was to focus on support problems. The projects on the list produced by the computer were then screened in more detail by the personnel of Foundation Sciences, Inc. In addition to the above criteria, the condition of data availability was added. The results of this screeneing produced the following list of six tunnels:

PHASE II WORK

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1. Metropolitan Highway Tunnels

2. Underground Power Complex

3. Arch Dam Diversion Tunnels

4. Inter-Basin Diversion Tunnels

5. Concrete Gravity Dam Diversion Tunnel

6. Western Washington Power Tunnel

Metropolitan Highway Tunnel - The Metropolitan Highway Tunnels are two, parallel, 54-foot span highway tunnels driven through a fractured volcanic ridge. The eastbound tunnel is 1,001.58 feet long and the westbound tunnel is 1,048 feet long. They are built on a 5 percent grade with an 8 degree curve. The tunnel section consists of a concrete liner 2.5 feet thick supported by two concrete sills 10 to 15 feet high and 6 feet wide at the base. Rock support and arch reinforcement was provided by 14-inch wide-flange cold-rolled ribs. Weight of the ribs varies from 48 to 103 pounds per foot with a spacing of from 2 to 4 feet. Extensive blasting and seismic records were kept due to the dense residential development in the project area. The cost of the project was $8,735,000.00 and was completed in 1969.

Underground Power Complex - This project includes an underground powerhouse and several associated tunnels. The main cavern is 477 feet long, 76 feet wide and 170 feet high. The tunnels include 4,300 linear feet of a 22-foot diameter tunnel, 910 linear feet of 42-foot diameter

tunnel, and various other shafts and tunnels. The project is located in a limestone and dolomite formation and is one of the few suitable underground structures in the Oregon-Washington area not constructed in volcanic rock.

The main cavities are supported by rock bolts with a maximum length of 20 feet. Sixty steel sets, 8 WF 31, were used together with rock bolts for support in the smaller tunnels. Gunite and concrete were used as lining. A special support problem developed necessitating the use of large cable tendons to hold the rock in place.

Extensive instrumentation and rock mechanics studies were performed during design and construction. The program consisted mainly of flat jack tests and plate loading tests. An instrumentation program to monitor the performance of the cantilever is in progress and records are available from 1966 to the present.

Arch Dam Diversion Tunnels - The tunnels are two, parallel, 40-foot span, gothic arch tunnels, 1300± feet in length. The uncommon shape of these tunnels was a result of an attempt to produce a more stable arch. Support was designed for steel sets or rock bolts at the contractor's option. The project was completed in 1964 for a cost of $1,520,700.00.

Inter-Basin Diversion Tunnels - The tunnels are small-diameter tunnels varying from 13.5 feet to 16.0 feet in diameter. They are con-

structed in basalt flows. The diversion tunnel is 11,381 feet long and the power tunnel is 7,272 feet long. The tunnels were completed in 1962 and 1963 at a cost well over the estimate because of serious water problems. During construction water up to 2,000 GPM was encountered and during the first dewatering of the tunnel, uplift pressure buckled the invert. Detailed geologic mapping was carried out in the tunnel. The small diameter and ease of support limit the usefulness of this tunnel for purposes of the detailed study. However, it is included here because of the interesting and severe water problems plus the failure of the lining.

Concrete Gravity Dam Diversion Tunnel - The diversion tunnel was built for a cost of $820,200.00. The tunnel is a horseshoe-shaped tunnel with a span of 30 feet and a length of 1,050 feet. It was driven in basalt and tuff and through nine shear zones with a maximum overburden of 150 feet. A major fallout problem occurred near the upstream portal. The support design was changed from rock bolts to steel ribs because the labor union refused to allow men to work under rock supported only by bolts. The tunnel was finished in 1965.

Western Washington Power Tunnel - The power tunnel is 6,236 feet long and has a circular section with a diameter of 15 feet. It was included despite the fact that it was completed almost 30 years ago, because the shape, support, span and lining were modified to fit the geologic conditions

encountered. There were a total of thirteen different section designs, twelve of which were used in construction. While the flexibility of the design and construction contract probably would not be applicable to current construction methods, it presents an opportunity to study efficiency of various sections. It was completed in 1942 at a cost of $1,307,000.00.

This summary was reviewed by the project officer and the principal investigator in a meeting at Portland, Oregon. As a result of that meeting it was decided to study the Underground Power Complex and the Metropolitan Highway Tunnel in detail and, if time and funds permitted, to also obtain more detail on the Inter-Basin Diversion Tunnels and the Concrete Gravity Dam Diversion Tunnel.

Data Gathering

Metropolitan Highway Tunnel - The material, while quite complete, is not well indexed and requires considerable searching. The material consists of the last remaining copies of the data and the owner does not wish to let it leave his possession; therefore, the material must be microfilmed on the premises. The contractor still has an office located in Portland, Oregon, where records are available; again, for inhouse reviewing. The personnel who worked on the job, both as contractor and engineer, were available for interviews.

Underground Power Complex - The contractor has most of the design computations and a visit was made to his office. Visits to the owner's office were also made and a considerable amount of material was microfilmed.

Secondary Projects - Data from the Concrete Gravity Diversion Tunnel has been supplied; the owner has a policy of compiling all of their data and publishing it in several reports all of which have been collected and microfilmed. Data from the Inter-Basin Diversion Tunnel was supplied by both the owner and the contractor. A visit to the owner's office was made to obtain copies of the tunnel data.

Conclusions

The data collecting phase has been more time consuming and more costly than originally estimated. The problem resulted from the large mass of information generally located in indifferent or nonexistent archive file systems. Therefore, it was necessary to spend much time to locate the desired information. The contacted agency generally was willing to allow access to the files but unwilling to spend any great time searching them. It was also difficult for the contacted agency to know which of the particular unbound data volumes, such as design calculation, would be of interest to the study.

Intensive Study of Pilot Projects

This portion of the program is the detailed study of the metropolitan highway tunnel, hereinafter referred to as Project "A" and the underground power complex referred to as Project "B". Each project is discussed individually beginning with Project "A". The format is somewhat different in each case as different points of interest developed under each study. Funds are not available to complete reports on the secondary projects, so no discussion of these projects is contained herein.

PROJECT "A"

Introduction

Location and General Description - Project "A" is located on a major access route into a major metropolitan city. The project consists of two similar arched-roof highway tunnels, spaced 85 feet apart, running generally west-east through a prominent basalt ridge. Each tunnel has a maximum cover of 165 feet, is built with a 5-percent grade and an 8-degree curve, is more than 1,000 feet long, and has a 58-foot span. Each consists of a rock section fully supported with steel ribs and completely lined with a minimum thickness of $2\frac{1}{2}$ feet of concrete plus a cut-and-cover earth section at the west portals. Project "A" was completed in 1969 at a cost of $8,600,000.00.

Exploration Program

Drilling from the Surface - Exploration began in 1960 and the cost of the entire drilling and soils testing program included foundation exploration for a nearby freeway interchange and the realignment of the highway. The program in the tunnel area consisted of the rotary drilling of 27 holes for a total of 1,056 linear feet. The average hole depth was 39 feet and the deepest was 174 feet. This drilling disclosed the following information.

The ridge is composed of basalt lava flows capped by a mantle of silt. The basalt flow is of Miocene age - Columbia River Basalt Formation.

The formation is a series of lava flows containing very few sedimentary beds. The thickness of an individual basalt flow is variable but rarely exceeds 50 feet. The thickest measurable flow encountered by test boring was 34 feet. The nature of the contact zones between flows varies from a sharp, relatively unweathered contact to situations where the two flows are separated by as much as 4 feet of severely weathered rock. Vesicular zones are common at the top and bottom of the lava flows but are generally more prominent and thicker at the top of the flows.

A mantle of intermixed silts, clayey silts, and sandy silts covers the basalt core of the ridge. The silts, generally considered to be of windblown origin (loess), vary from a thickness of zero on the slopes of the ridge to as much as 42 feet on top of the ridge over the centerline of the south tunnel. Often a zone of silty clay up to 10 feet thick and containing weathered basalt fragments lies between the silt and the basalt. The silts are highly unstable where excessive moisture conditions exist.

Exploration Adit - A pilot tunnel with dimensions of 5 feet by 7 feet was driven near the crown of the eastbound tunnel at a cost of $90,000.00, a figure which represents slightly more than 1 percent of the total project cost. Seven additional exploratory drill holes were made from the adit: two vertical downhole; three 60° up, southside; one 30° up, southside; and one 60° up, northside.

The pilot tunnel was completed in March, 1964, and followed the top portion of the proposed eastbound tunnel. Geologic maps and photographs were produced that show the physical conditions encountered by the pilot tunnel. The important information derived from this work applied to design are as follows.

Stratification - The rock through which the tunnel passes consists of a series of stratified basalt lava flows. The individual strata or lava flows are thick enough so that it is very unlikely that more than one of the boundaries between the lava flows or contact zones will occur at any one point along the course of the main tunnel. One such contact zone can be followed almost continuously from the east portal through 70 percent of the tunnel.

Jointing - A major joint system is present with 3-foot-plus spacings and what appears to be a secondary joint system with spacings averaging ±5 inches. The secondary jointing is quite tight with little or no weathering along the joint surfaces; whereas the major joint system is more open and has developed weathered shells up to $\frac{1}{4}$-inch thick along the joint surfaces. A spalling or caving condition that required shoring, and then resulted in overshooting at some locations in the pilot tunnel, was attributed to this joint pattern.

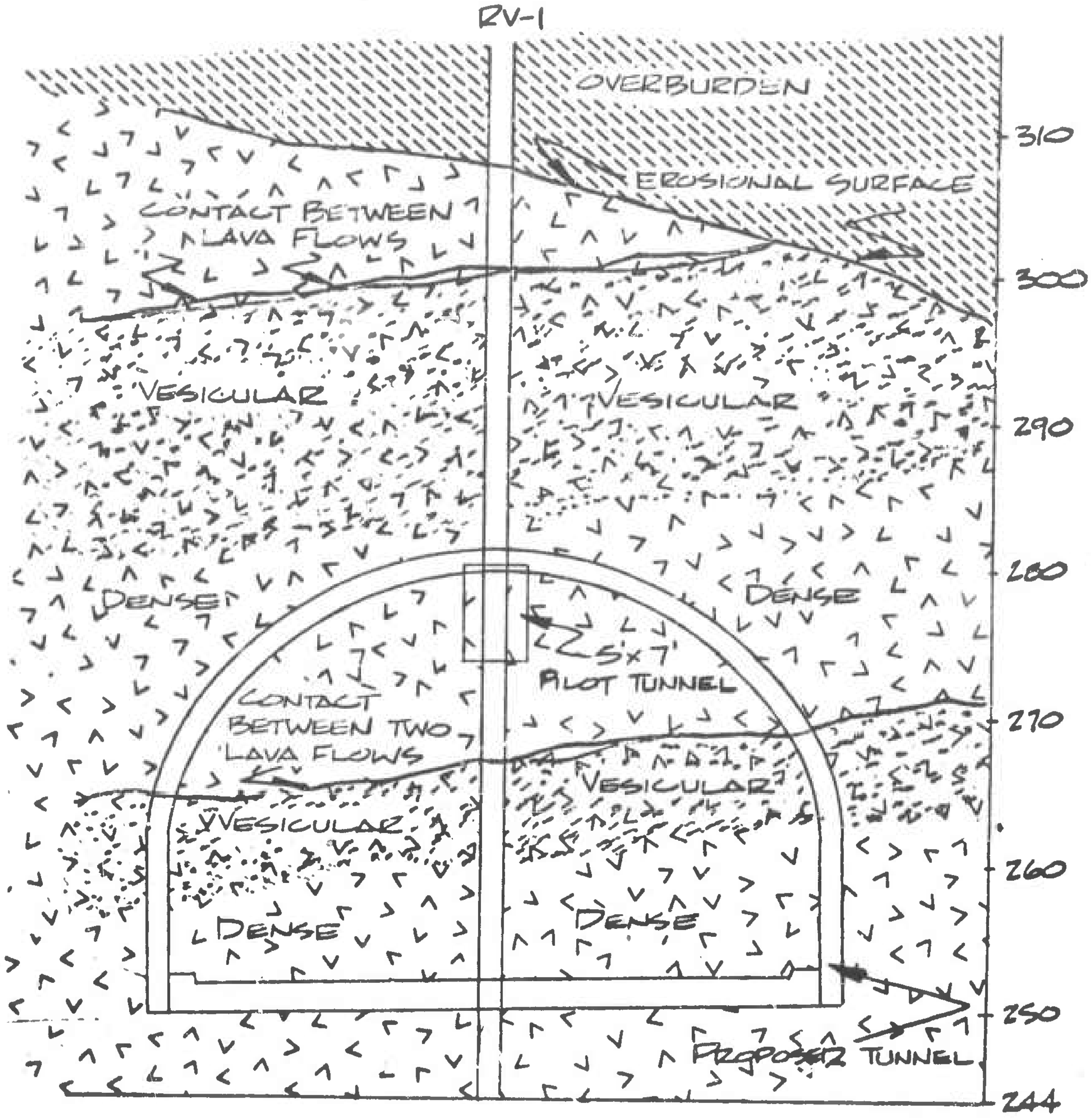
Expansive Clays - Highly expansive clays, either coating joint surfaces or filling cavities, are found throughout the pilot

tunnel. The clays are consistently highly plastic and appear to be in their most expanded state. There is no evidence that they are exerting stress on the rock. The clays are most abundant in a minor fault zone near the east portal.

The combined results of the test adit and the drilling program produce the geologic cross section shown in Figure 1.

Seismic Study of Blasting - The driving of the pilot tunnel afforded an excellent opportunity for the designer to study the effects of blasting in an urban-residential area. Vibrations from the blasting were regularly measured during the pilot tunnel construction. Generally, the seismograph was located either directly over the blast or in the vicinity of the nearest structure. Where complaints about the blasting were involved, vibration measurements were made in the foundation area of the structure or in the structure itself. The measurements were made with a Sprengnether Seismograph and maximum particle velocity was computed from the wave traces.

The percent of the generally accepted safe-velocity limit (2 inches per second) was computed using the maximum resultant velocity from each measurable record. The location of the seismograph with respect to centerline and its direct-line distance from the blast was determined for all of the vibrations recorded. Logs of all the charges were kept to record: the charge location, shot holes drilled and depth, delays used, maximum charge



IDEALIZED SECTION THROUGH STATION 39+75 USING DATA FROM RV-1

Figure 1.

per delay, and the corresponding seismic velocity record if one was taken.

Vibration measurements of the blasting made in the vicinity of the structures generally averaged 15 to 25 percent of the safe-velocity limit. The velocity measurements rarely exceeded 40 percent of the safe limit and the highest was 75.5 percent near structures.

Figure 2 shows the predicted charge per delay that could result in ground vibrations reaching the 2-inch-per-second safe-velocity limit. The chart was constructed using the most representative data from vibration records taken during construction of the pilot tunnel. The maximum resultant vibration intensity and corresponding charge size were determined for each of the records used. The maximum safe charge was then determined on a direct proportion basis using the actual charge exploded and the resulting vibration intensity. The computed maximum safe charge was then plotted above that point in the tunnel where the actual charge was detonated. This approach tends to minimize the effects of variables such as physical characteristics of the rock thickness, and angular relationship (from the vertical) of the seismograph location and the charge location. All of these factors could influence the ground vibration resulting from any one charge of explosive. The curve for the first 100 feet in from the east and west portals was controlled by a combination of the computed safe charges described above

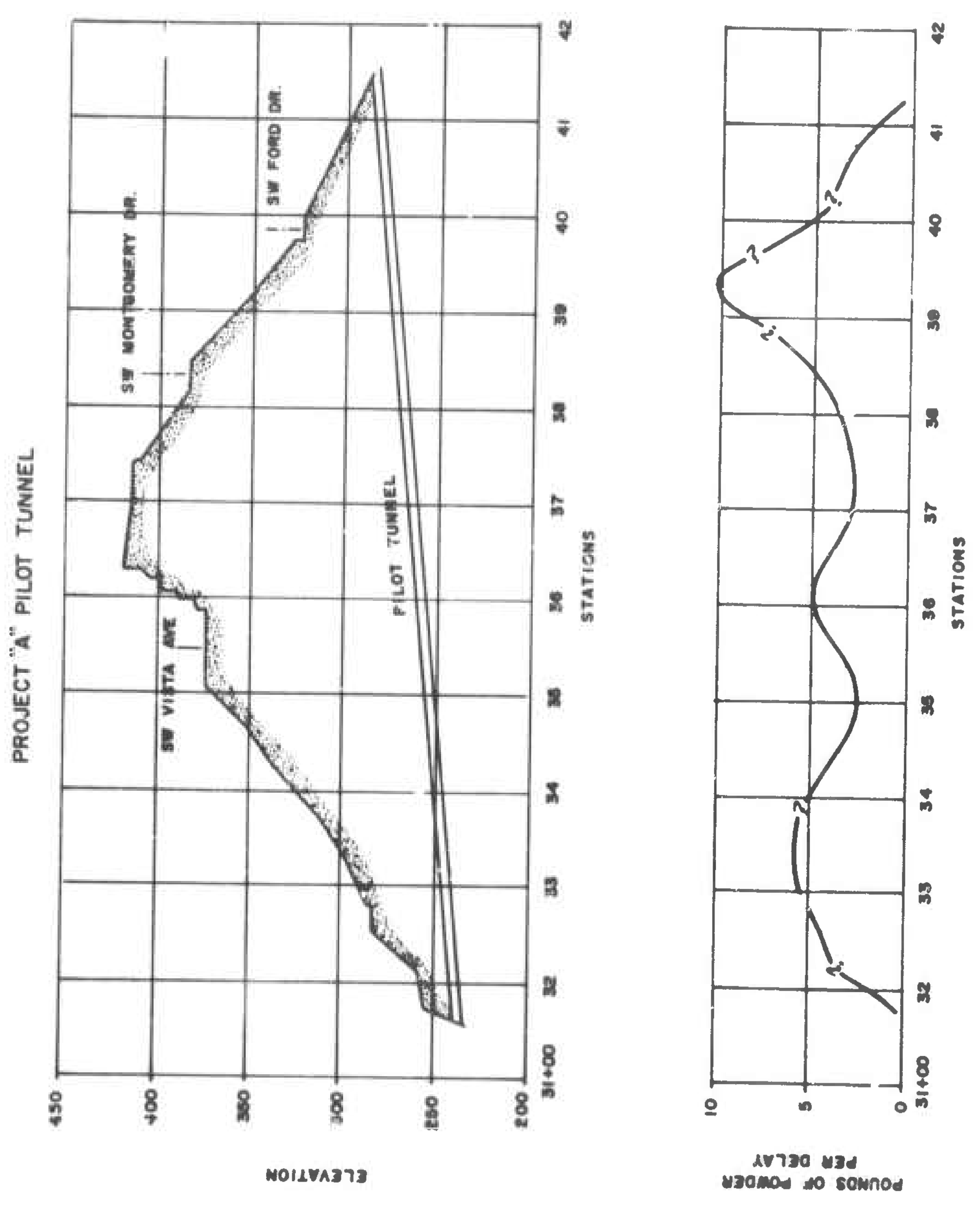

PROJECT "A" PILOT TUNNEL
SW VISTA AVE
SW MONTGOMERY DR.
SW FORD DR.
PILOT TUNNEL
ELEVATION
450
400
350
300
250
200
31+00
32
33
34
35
36
37
38
39
40
41
42
STATIONS
POUNDS OF POWDER PER DELAY
10
5
0
STATIONS

Figure 2.

and the observed reaction to air shock waves from the charges detonated. The following points should be kept in mind when interpreting the graph.

1. Points below the curve represent the predicted safe charge per delay that very probably can be used without exceeding the safe-vibration velocity of 2 inches per second. It has been found that each delay charge causes its own independent ground vibration. The energy of one delay period is very short.

2. Many of the computed safe-charge sizes fell above the curve, meaning that there will always be the question of safety when using a charge larger than that indicated by the curve. Any charge size falling below the curve would stand little, if any, chance of exceeding the safe-velocity limit.

3. The dashed portions of the curve indicate areas in the pilot tunnel where it was not possible to gather dependable blast vibration data for computing the maximum safe charge.

Specifications requiring that the maximum velocity of blast vibrations be kept below 2 inches per second are becoming more and more common on construction projects. The above method of blasting control demonstrates one suitable means of controlling charge sizes during tunnel construction.

Tunnel Design

General Requirements - Each bore is to provide room for a three-lane roadway, 42 feet in width between curbs, with 2-foot-wide safety walks on each side. The clear ceiling height at the center of the roadway is 17.5 feet.

Support Design - The use of rock bolts as a support medium was discarded early in the design after an inspection of the pilot tunnel was performed. The decision was based upon the following opinions expressed during the inspection:

1. successive shocks and vibrations could very well cause rock fallout in the areas where rock is not continuously supported either in the overhead or along the walls;

2. a length of 38 feet was suggested for rock bolts, should they be used;

3. the length of the rock bolts might exceed the thickness of the flows lying above the tunnel roof and as a consequence the anchors of the rock bolts may fall in the weathered, extremely fractured, weak, and compressible material similar to that which is exposed in the tunnel in the interflow zones.

No further consideration was given to rock bolts and the tunnel was supported by conventional steel sets designed by the methods outlined in Proctor and White (1946). The assumptions used in the design were:

1. rock under dry conditions,

2. working stress in the steel of 18,000 psi,

3. multiple drift tunneling,

4. 24 feet of rock load,

5. no side thrust.

Considerable attention was given to the selection of the design load for steel sets. A study of the joints and fracture patterns was made in the pilot tunnel and the rock loads were estimated by using the the table in Proctor and White (1946). Preliminary design began using rock loads that varied along the tunnel with a maximum load of 100 feet before construction practice and economic judgment was exercised to produce the 24-foot figure used in the final designs. Standard set design, as outlined in Proctor and White (1946), will tolerate this type of judgment for set selection and will tolerate errors in judgment as large as 900 percent.

Lining Design - The lining in the rock portion of the tunnel was designed using Proctor and White (1946) and assumed the lining to be a continuously blocked rib capable of supporting the entire rock load. This resulted in a combined support capacity of twice the design load, discounting the safety factors inherent in the steel and concrete design and those contained in the rock load table by Proctor and White (1946).

Footing design for the rock section was controlled by the strength of the concrete. The footings in the cut-and-cover sections were founded

on caissons to firm rock, and in neither instance was the bearing strength of the rock a factor controlling the design.

The design of the cut-and-cover section, ventilation, and lighting are not contained in the scope of this report, but appear to be in agreement with the Bureau of Public Roads standards.

<u>Construction</u> - Two contracts were let for the project construction. The first contract included:

1. the 1,001-foot eastbound tunnel,
2. the 99-foot cut-and-cover portion of the westbound tunnel

The second contract included:

1. the 1,048-foot westbound tunnel,
2. paving, lighting and ceramic tile lining in both tunnels.

The successful bidder on the first contract was also the successful bidder on the second contract.

<u>First Contract</u> - The first contract was awarded on November 19, 1965. The work included grading, paving, retaining walls, and an overpass. The contract amount was $4,181,131.00.

Scheduling - The construction schedule called for the side drifts to be excavated with a height from the tunnel invert to the springline, and a heavy sill to be constructed in the side drifts. Upon completion of the side drifts and sills, the main tunnel arch was to be excavated

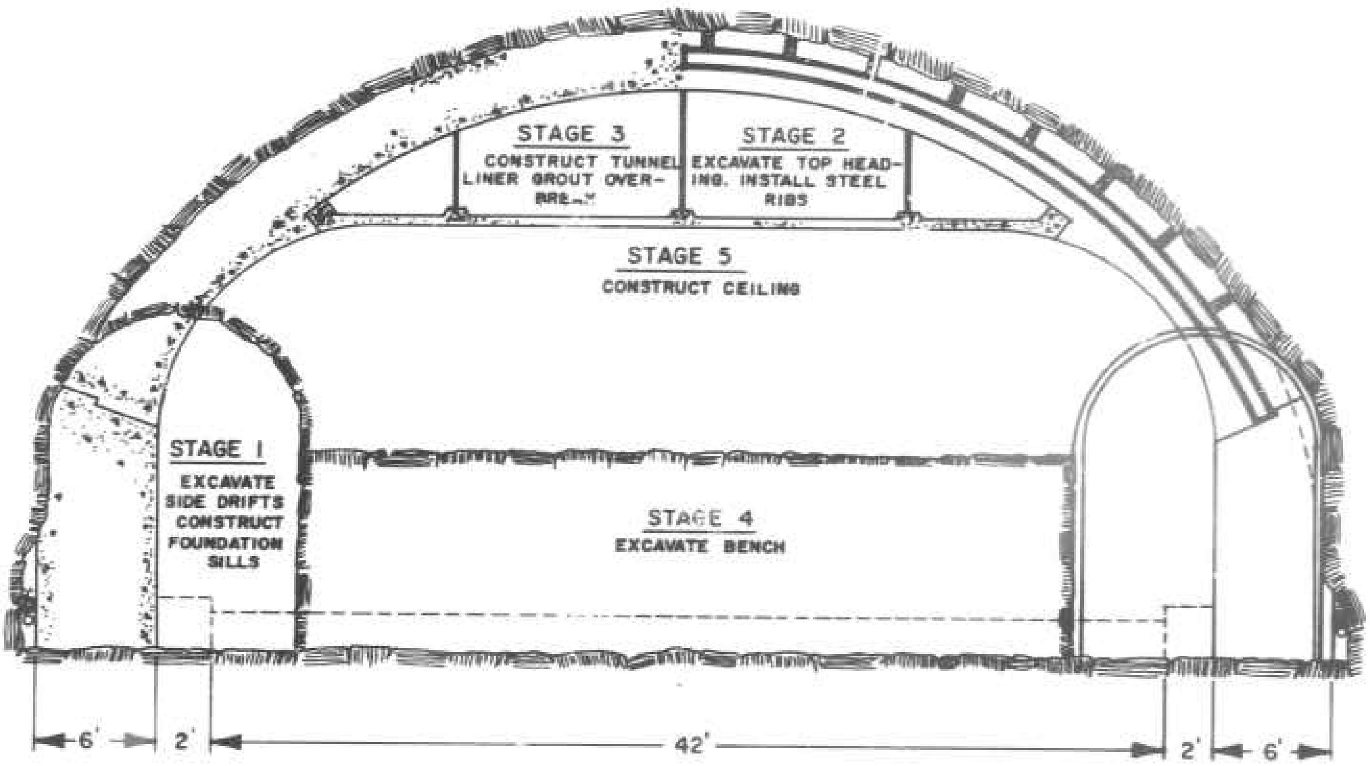
and the lining to be installed. The Contractor would then remove the bench to grade and install the ventilation and false ceiling. Figure 3 is a typical section through the tunnel showing the multiple drift heading used for the construction.

Side Drifts

Support - The design and support of the side drifts were left to the Contractor. The outside payline was established for the entire tunnel and payment for the side drift excavation was computed from that line and the side drift profile. Steel ribs were selected for side drift support because excessive labor costs for removal of rock bolts from the inboard side of the drift eliminated rock bolting from consideration. The use of ribs also allowed all the inboard ribs (approximately $20,000.00 worth) to be salvaged and used again during the second contract. Temporary supports for the side drifts were designed by the method given by Proctor and White (1946), and an 8 WF 31, 2-piece rib set on 5-foot centers was selected.

Equipment - The equipment used by the Contractor for construction of the side drifts was normal mining equipment with the exception of the drilling jumbo. The jumbo was built on a small Euclid truck frame. Six Gardner-Denver D-93 drifter drills mounted on hydraulic booms were spread on three levels. Mucking equipment consisted of

PROJECT "A" TUNNEL
STAGE CONSTRUCTION



Radius of the arch = 27'

NOT TO SCALE

Figure 3.

two Koering, Model 60, dumptors and an Eimco 105, $1\frac{1}{2}$-yard overshot loader. Three Gardner-Denver compressors, displacing 1395 cubic feet per minute each, supplied compressed air to the face through 6-inch lines. A 4-inch water line was supplied to each face also. The fresh air was supplied through a 21-inch aluminum pipe by a 30-inch, 11,000 cfm fan, driven by a 20-horsepower electric motor.

Construction Method - The east portal area was excavated to grade, and the face was supported with rock bolts and steel mesh. The side drift portals were drilled and supported with $1\frac{1}{2}$-inch steel crown bars. Three steel sets were erected and completely lagged before the initial shot. The first round was detonated on January 21, 1966, in the right drift. The left drift was prepared in a similar way; excavation began on February 8, 1966. The side drifts were blasted using a modified burn cut and 5-foot rounds with standard delays.

Both side drifts were excavated simultaneously allowing an efficient use of men and equipment. The load- shoot- ventilate- and muck-cycle was performed in one drift while the setting of steel and drilling progressed in the other drift. A single drill jumbo and set of mucking equipment was then able to handle both headings. Using this alternating method, as many as five rounds per shift were shot in the side drifts. The ribs were always set directly behind the face and no more than 7 feet of tunnel was unsupported at any one time.

The right heading was driven until April 11, 1966, when the Engineer advised the Contractor to stop because the heading was completely in clay. The left heading was stopped 85 feet from the west end of the tunnel for the same reason. On May 19, 1966, concrete placement began in the sills. Two forms were used in each drift: alternate 20-foot sections were poured using a bulkheaded form; the fill-in pours were made using a straight form. Construction of the sills was completed in four months. After the sills were complete the inboard legs of the ribs were salvaged.

Top Heading, East Tunnel - The first tunnel rib was set in the top heading at the east portal on August 8, 1966. The actual entry to the top heading was complicated by the skewed condition of the face. The right side was in solid rock and the left side was in silty clayey soil. Six ribs were set back from the face and 4-inch by 8-inch treated wood lagging was installed in order to make a protected working area at the face. One and one-eighth-inch-diameter crown bars 20 feet long were installed on 1-foot centers. The rock portion of the face was lightly shot and the soil removed by spade until room enough was made for another rib. The contractor continued to advance by hand methods, spading the soil zone and barring and chipping the rock, until the face was straight and clear of the soil zone.

On August 15, 1966, the first full-face round was shot in the top heading. After a few days to train the work crew, progress quickly reached 2 to 4 rounds per day. Based on 4-foot rounds, the work cycle was 2 hours and 30 minutes which is broken down as follows:

Muck out	30-45 minutes	0:30 - 0:45	20%
Drive in jumbo	±15 minutes	0:45 - 1:00	±10%
Set and block rib	30-45 minutes	1:00 - 1:30	20%
Drill round	±15 minutes	1:30 - 1:45	±10%
Load round	±30 minutes	1:45 - 2:15	±20%
Shoot and ventilate	±15 minutes	2:15 - 2:30	±10%

During the excavation of the top heading, there was extensive overbreak in the crown. This overbreak was related directly to the existence of the pilot tunnel and the limitations of the Contractor's jumbo. The pilot tunnel had been open and unsupported or supported by twelve sets for more than two years and its exposed rock had seriously deteriorated. As much as 8 feet of rock dropped out of the fractured zone above the crown as the heading was advanced. The jumbo could carry only one rib into the tunnel at a time making it difficult to double the support on any round. In order to have the maximum efficiency in the excavation, the Contractor desired to shoot the maximum length of the round and install the ribs at the maximum spacing. The use of the greater spacings in some areas caused excess overbreak which was controlled by installing $1\frac{1}{4}$-inch pipe spiles on 15-inch centers on the crown. The spiles were 10 feet long and were installed

over the last rib and under the second to the last rib.

The overbreak was filled with timber cribbing and tightly wedged against the steel ribs. Pre-set grout pipes were installed and the overbreak was later backfilled with grout. The cribbing was not removed prior to concrete placement.

Blasting - The blasting in the eastbound tunnel was carefully controlled due to the proximity of residential development. The Contractor did not, at any time, use a charge in excess of the charges dictated by the charge-delay curve designed during the pilot tunnel construction, Figure 2. The usual maximum charge was $5\frac{1}{2}$ pounds per delay. As a result of this program, ground accelerations during the driving of the main tunnel were less than those experienced during construction of the pilot tunnel.

Equipment - A new, larger jumbo was built for the top heading. The jumbo was on a large Euclid truck chassis with three levels. Two Gardner-Denver drifter drills and two Pitman HC-100 hydralifts were mounted on the top level; three drifters were mounted on each of the two lower levels. The same equipment, as was used in the side drifts, was used to deliver compressed air and water to the face in the top heading. Ventilation was provided by a 20-horsepower fan which was installed in the west portal of the pilot tunnel. Mucking equipment consisted of a caterpiller, 977 H traxcavator with a 2 5/8-yard side dump bucket, two

dumptors and two 10-yard diesel dump trucks.

Tunnel Lining - On March 10, 1967, the top heading was holed through. The arch forms were skidded into the tunnel and the first arch pour was made on March 22, 1967.

When the concrete arch construction was about half complete, the grouting operation began. The grout, which was a mixture of one part cement to three parts sand, was placed through pre-set steel pipes. The hookup was made and grout was pumped until it returned from the de-air line. Then the air line was closed and pumping continued at low pressure until refusal or grout flowed from an adjacent hole. If grout flowed from an adjacent hole, it was considered to be completely grouted and was closed and the de-air line left open while pumping continued until grout flowed from the air line. The air line was then closed and pumping continued until refusal. As many as 12 pipes returned grout from a single hookup. A total of 1000 cubic yards of concrete and 594 cubic yards of grout were placed outside of paylines. Grouting was completed in early June, 1967.

Bench Excavation - A D-9 Cat, equipped with two ripper teeth and a blade, was used to excavate the bench to grade, which was a new approach to this type of excavation. The Cat averaged 290 cubic yards of rock excavation per day. No blasting was required.

Final Phase - The final phase of construction was the pouring of the false ceiling and the curbs plus the construction of the control room. This was completed in approximately two months. The final tunnel work was completed on September 29, 1967. Incidental work at the east end and clean up continued until November 27, 1967. The Contractor submitted a request for extension of time past the specified completion date of September 30, 1967, based on delays in the award of the contract and the redesign of the west portal. Time extension was approved on April 23, 1968.

The final voucher was submitted April 25, 1968, and the final payment made on July 30, 1968. The summary of costs are as follows:

Contract cost		$4,194,356.04
Engineering costs		345,874.41
Other costs		46,040.02
	TOTAL	$4,586,270.47

Second Contract - The second contract was awarded on February 16, 1968 . The work included grading, paving tunnel illumination, and signs for both tunnels. The contract amount was $3,743,984.00.

With only minor variations, the methods and equipment used in the westbound tunnel were the same as those used in the eastbound tunnel.

The side drifts were excavated using the same equipment

and methods as used previously. The Contractor had experienced difficulty in the eastbound side drifts with the mud formed by the drill water in the tunnel invert. This was avoided by pouring a concrete floor in the drifts prior to construction of the sills. The extra concrete was at the Contractor's own expense with costs amounting to $6,000.00. However the savings due to more efficient operation were well in excess of that amount.

The rock was generally looser and more fractured in the westbound tunnel. During the arch excavation, the Cat 977 loader was often used to knock enough rock loose from the face to set another rib; after which, the remainder of the face was shot.

Overbreak was much easier to control in the westbound tunnel due to the absence of a pilot tunnel. There was only a single $2\frac{1}{2}$ to 3-cubic-yard fallout which was caused by incorrect blocking of one rib. The lack of overbreak produced a substantial reduction in the amount of concrete and grout placed outside of the payline, although the Contractor did not release information as to precise quantity.

Evaluation

Use of Exploration Information - The information supplied by the drilling program, the test adit and laboratory testing consisted of a geologic cross section and profile, joint and fracture pattern studies,

unconfined compressive strengths. specific gravities, and blast control data. There is no record showing any use of the unconfined compressive strength data in either design or construction of the project. The joint and fracture pattern studies were used in the preliminary design of the steel sets, but in the final design they were not used because of the nature of the Proctor and White (1946) design method. In a practical Proctor and White design, the rock type is quite insensitive when compared to the variables of blocking and set spacing, negating any real value in knowing the specific rock type requiring support. The geologic profile and cross section were used to supply general insight and the specific gravity information was used for rock loads in set design. In conclusion, the only exploratory information used specifically in the design of the tunnels was the results of the specific gravity tests. It appears, then, that in the design phase less than $1,000.00 worth of test results were used of the more than $100,000.00 spent on exploration.

In the construction phase, the only exploration information used was that obtained from the blast vibration studies. The methods suggested in these studies were followed quite closely by the Contractor and succeeded in protecting him from law suits on blast damage. However, two suits on blast damage due to tunnel excvation were filed against the Engineer. One suit was settled out of Court and the other resulted in a

minor judgment against the Engineer.

Comparison of Methods With State-of-the-Art Today - The tunnel support was designed using methods which at the time were some 20 years behind the state-of-the-art. The support design could have incorporated rock bolt support and possibly even rock bolt and pneumatically placed concrete lining. The construction of the tunnel was current with the state-of-the-art except for the multiple drift heading which was required by the contract. The Contractor advanced the state-of-the-art by ripping the material in the bench portion of the tunnel.

Use of Rock Mechanics - No use of rock mechanics was made throughout the design and construction of the project. The Engineer made an attempt to instrument some steel sets, apparently for research purposes. No valid conclusions could be drawn from the data, and the instrumentation was discontinued.

Potential Savings - Potential savings could have come from two different areas, both concerning rock bolting. The pilot tunnel was primarily unsupported, however timber sets were used in some areas. Either of the conditions allows progressive loosening of the arch of the tunnel. Because the pilot tunnel was located in the crown of the main bore, this critical area was allowed to loosen for more than a year prior to excavation resulting in a large amount of overbreak. If the entire crown of the

pilot tunnel had been rock bolted; or, better yet, had the rock bolts for the main bore been installed as the pilot tunnel was advanced; or had the pilot tunnel been located elsewhere other than along the crown of the main bore, $70,000.00 of overbreak repair could have been saved.

Had rock bolts been used for the main bore support, considerable savings could have resulted. A study made by Foundation Sciences' personnel shows that a 16-foot rock bolt on a 4-foot center would support the project opening allowing a 6-foot reduction in the tunnel diameter. A cost comparison by FSI of the two systems is shown below.

Structural Steel Ribs	$ 238,665.20
Class A Concrete	838,020.48
Reinforcing Steel	54,093.84
	$1,130,779.52
Rock Bolts	$ 290,000.00
Class A Concrete	420,000.00
Reinforced Steel	18,000.00
	$ 728,000.00
Net Lining Savings	$ 402,000.00
Excavation Savings	$ 360,000.00
TOTAL SAVINGS	$ 762,000.00

The savings would have amounted to $762,000.00 per bore for a total of $1,524,000.00 plus $70,000.00 for the pilot tunnel, all of which results in a possible savings of $1,594,000.00 or 16.5 percent of the total cost.

Monitoring of Complete Project - No structural monitoring of the complete project was performed.

Conclusions

In conclusion, Project "A" is considered to be representative of the state-of-the-art of tunneling in basalts of Washington and Oregon to date. Little money was spent on exploration (less than two percent of the project cost), and little or no use was then made of this exploration information in design. The design of the tunnel support systems was virtually non-existent and most of the support design was performed during the construction phase by the Contractor's supervisory personnel. These practices resulted in excessively high safety factors in the support and linings used, and significantly increased the cost of the tunneling.

PROJECT "B"

Introduction

Location and General Description - The project is located in northeastern Washington and consists of an underground hydroelectric generating station for a high thin arch dam, see Figure 4. The powerhouse is 477 feet long, 76 feet wide, 170 feet high, and is located approximately 450 feet below the ground surface.

Geology - The project is located entirely within the Metaline Limestone Formation of the northern Rocky Mountain province. The area has a complex and varied geologic history including marine deposition, intense folding, faulting, and chemical alteration. Unconsolidated Quaternary deposits of fluvial and glacial origin overlie the area. During the retreat of the last glaciation, complex erosional features were developed in these sediments. Following glaciation, the Pend Oreille river excavated its present valley in the glacial debris and the underlying Metaline limestone.

Following is a description of the Metaline limestone from surface down:

Mottled, dense, gray limestone. Few chert nodules.	150 feet
Mottled, dense, gray limestone. Many chert nodules.	450 feet
Fine-grained, cream-colored dolomite particularly in the upper part; alternating layers of black and white dolomite.	1,200 feet

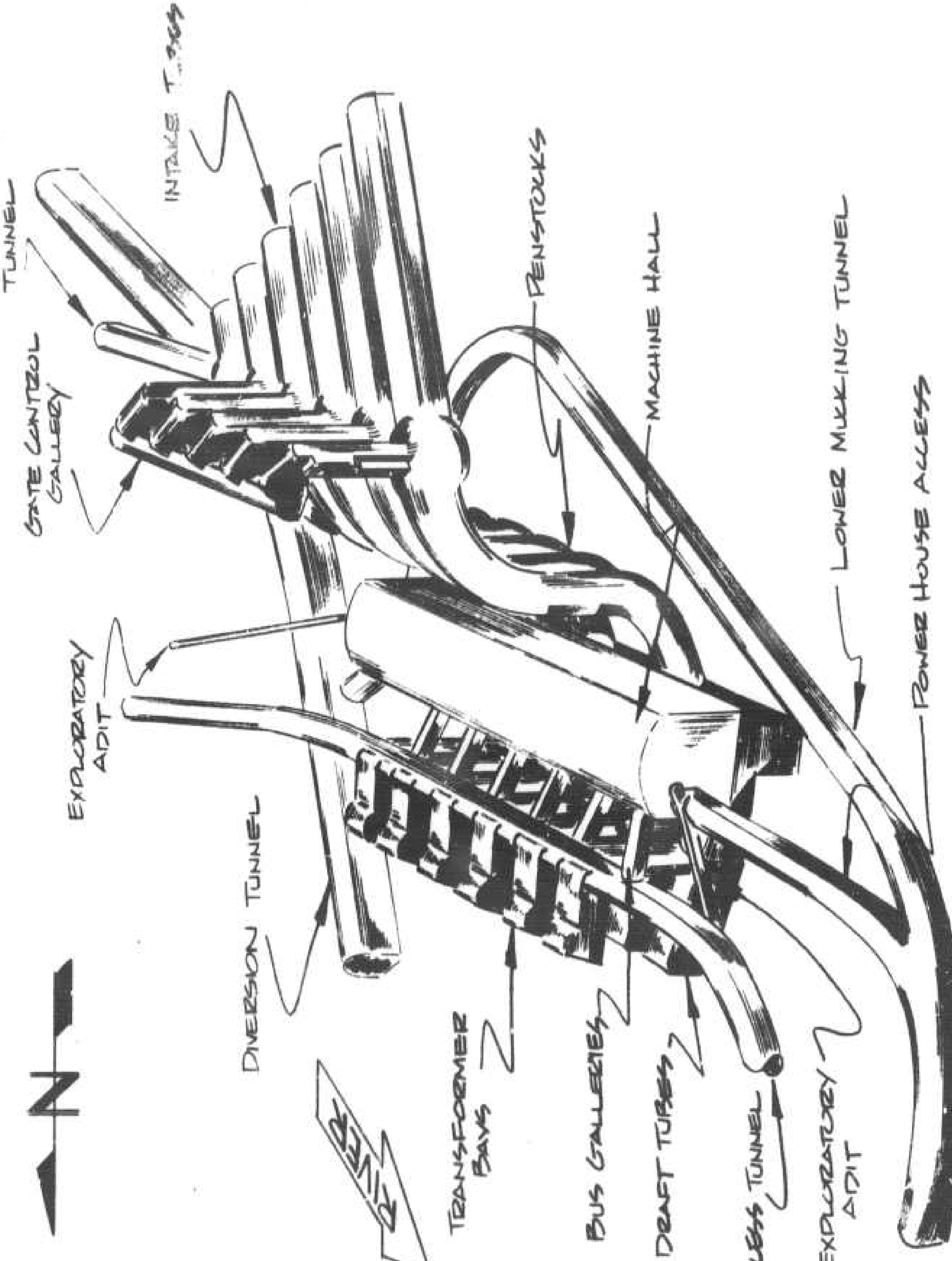

UPPER MUCKING TUNNEL
INTAKE
GATE CONTROL GALLERY
PENSTOCKS
MACHINE HALL
LOWER MUCKING TUNNEL
POWER HOUSE ACCESS
EXPLORATORY ADIT
DIVERSION TUNNEL
TRANSFORMER BAYS
BUS GALLERIES
DRAFT TUBES
DAM ACCESS TUNNEL
EXPLORATORY ADIT
RIVER
N

Figure 4.

Interbedded limestone and limy shale; locally dolomite.	1,200 feet
Total Thickness	3,000 feet

In the vicinity of the dam, alteration of the rock is confined to dolomitization and to localized zones of silicification. Outcrops are prominently bedded and dips of 40 to 50° S, (upstream) are found at the dam site. In the vicinity of the dam, faults and brecciated zones are common and appear in surface exposures. The fault breccias are wholly or partially healed. Jointing is common and locally conspicuous; however, no regular well-defined patterns have been detected. Groundwater is confined to fractures, and in the lower excavation of the powerhouse, solution cavities with estimated groundwater flows of 800 GPM were encountered.

Exploration Program

Surface Exploration - Exploratory drilling at the project site began as early as 1944-45. Extensive geologic studies, using aerial photography combined with surface reconnaissance, supported with drilling, were performed on the dam site and throughout the reservoir area. Ninety-eight holes were drilled at the site from 1961 to 1964. Thirty-three core holes were drilled in the powerhouse area, seven were drilled in the right abutment, and thirteen in the left abutment area. Four core holes were drilled from

the right abutment exploratory tunnel, six holes were drilled from the diversion tunnel, and thirty-two holes were drilled in the left abutment exploratory tunnel. Three surface holes, drilled in the right abutment in 1964, completed the exploratory drilling program.

Subsurface Exploration - Two 6-foot by 8-foot exploratory adits were driven at the site; one at elevation 1,790 through the machine hall xis to a point 50 feet from the proposed dam-rock contact in the left abutment, and the other into the right abutment at elevation 1,825. The second adit was later used for access from the operating deck on the downstream face of the dam.

Laboratory Testing - As part of the 1945 exploration program, samples from the site were tested for compressive strength and bending strength, see Table 1. The dynamic moduli of elasticity shown on this table were obtained by sonic methods and the static moduli were determined by bending and compression testing.

In Situ Testing - The in situ rock testing consisted of flat jack tests, extensometer installations, and plate bearing tests. The results of the in situ tests are shown on Table 2, Table 3 and Table 4. Later, additional laboratory testing and finite element analysis were conducted in order to refine the data obtained by the in situ testing. However, the laboratory results were regarded only qualitatively, as a rock mass often displays porperties different from those

Table 1
STRENGTH TESTS OF LIMESTONE CORES - PROJECT "B"

			Modulus of Elasticity		Triaxial Shear Tests	
Depth (feet)	Test	Strength (psi)	Static (psi)	Dynamic (psi)	Lateral pressure (psi)	Maximum axial load (psi)
158	Compression	5,070				
85	Shear				2,000	23,140
68	Compression	4,400				
17	Shear				2,000	18,120
275	Compression	11,960				
169	Shear				2,000	6,430
181	Compression	5,800				
231	Shear				2,000	20,500
65	Compression	7,460				
220	Shear				2,000	13,830
78	Compression	10,230				
52	Shear				2,000	15,680
108	Compression	5,510				
261	Shear				2,000	27,900
262	Shear				1,000	11,[illegible]00
18	Flexure	635	1,197,000			
30	Shear				2,000	19,500
31	Compression	3,911	1,850,000			
90	Shear				2,000	13,600
88	Flexure	1,060	1,365,000	3,867,000		
280	Shear				2,000	13,100
146	Flexure	442	626,000	4,118,000		
146	Shear				2,000	9,500

Table 1 (cont.)

STRENGTH TESTS OF LIMESTONE CORES - PROJECT "B"

Depth (feet)	Test	Strength (psi)	Modulus of Elasticity: Static (psi)	Modulus of Elasticity: Dynamic (psi)	Triaxial Shear Tests: Lateral pressure (psi)	Triaxial Shear Tests: Maximum axial load (psi)
104	Flexure	415	471,000	3,494,000		
204	Compression	7,896	4,000,000			
205	Tension	100		3,930,000		
250	Shear				2,000	17,400
265	Compression	7,190	3,650,000			
191	Shear				1,000	15,900
42	Compression	9,500	5,050,000			
233	Flexure	683	1,400,000	4,331,000		
233	Shear				1,000	9,700
118	Flexure	744	2,500,000	6,690,000		
51	Tension	355		9,025,000		
51	Compression	16,384	5,250,000			
285	Shear				1,000	16,900
283	Compression	8,510	5,150,000			
226	Tension	118		8,330,000		
191	Compression	10,153	2,940,000			
191	Tension	674		9,247,000		
238	Flexure	621	1,860,000	3,297,000		
238	Shear				2,000	29,200

TABLE 2
FLAT JACK TEST RESULTS PROJECT "B"

Site No.	Stress	Displacement at Beginning of Jack Test (in.) d			Cancellation Pressures (psi) P_c			(psi)	Deformation Modulus (psi x 10^6)		
		6" A Pins	6" B Pins	10" Pins	6" A Pins	6" B Pins	10" Pins		6" A Pins	6" B Pins	10" Pins
FJ-1	Vert.	.0114		.0077	3,540		2,215	3,725	5.8		4.5
	Hor.	.0105		.0068	4,225		3,225	2,878	7.6		7.4
FJ-2	Vert.	.0054	.0045	.0037	1,500	1,385	1,170	1,888	5.2	5.8	4.9
	Hor.	.0068	.0066	.0056	1,825	2,075	1,765	1,352	5.0	5.9	4.9
	Trans Roof	.0065		.0057	2,715		2,400	1,620	7.8		6.6
	Right Cor.	.0133		.0065	5,950 (assumed)		3,540	1,620	8.4		8.5
	Left Cor.	.0085		.0062	4,370		3,950	1,620	9.6		9.9
FJ-3	Vert.	.0098		.0052	4,930 (assumed)		2,950	850	9.5		8.8
	Hor.	.0049		.0039	750		950	3,940	2.9		3.8
FJ-4	Vert.	.0064	.0069	.0053	540	650	575	327	1.6	1.8	1.7
	Hor.	.0050	.0052	.0040	350	380	250	588	1.3	1.4	1.0
	Trans Roof	.0131	.0157	.0085	620	730	500	457	0.9	0.9	0.9

TABLE 2 (cont.)
FLAT JACK TEST RESULTS PROJECT "B"

Site No.	Stress	Displacement at Beginning of Jack Test (in.) d 6" A Pins	6" B Pins	10" Pins	Cancellation Pressures (psi) P_c 6" A Pins	6" B Pins	10" Pins	(psi)	Deformation Modulus (psi x 10^6) 6" A Pins	6" B Pins	10" Pins
FJ-4 cont.	Right Cor.	.0043		.0051	1,080		1,500	457	4.7		4.6
	Left Cor.	.0079		.0080	750		810	457	1.8		1.6
FJ-5	Vert.	.0100		.0065	750		710	176	1.4		1.7
	Hor.	.0050		.0032	195		157	730	0.7		0.8
FJ-6	Vert.	.0100	.0105	.0089	1,000	1,000	850	1,495	1.9	1.8	1.3
	Hor.	.00259	.0333	.0282	1,480	1,690	1,375	950	1.0	1.0	0.8
FJ-7	Vert.	.0039	.0053	.0031	280	420	230	187	1.3	1.5	1.2
	Hor.	.0050	.0053	.0030	195	260	105	310	0.7	0.9	0.5
FJ-8	Vert.	.0115		.0066	3,755		2,600	2,000	6.2		6.2
	Hor.	.0041		.0033	2,200		1,800	3,177	10.1		8.5
	Trans Roof	.0110		.0071	2,450		1,455	2,588	4.2		3.2
	Left Cor.	.0071		.0041	2,500		1,575	2,588	6.6		6.0
	Right Cor	.0172		.0097	-----		-----	-----	---		---

TABLE 2 (cont.)
FLAT JACK TEST RESULTS PROJECT "B"

Site No.	Stress	Displacement at Beginning of Jack Test (in.) d: 6" A Pins / 6" B Pins	Displacement (in.) d: 10" Pins	Cancellation Pressures (psi) P_c: 6" A Pins / 6" B Pins	Cancellation Pressures (psi) P_c: 10" Pins	(psi)	Deformation Modulus (psi x 10^6) 6": A Pins / B Pins	Deformation Modulus (psi x 10^6): 10" Pins
FJ-9	Vert.	.0105	.0071	760	480	217	1.4	1.1
	Hor.	.0026	.0011	270	165	620	2.0	2.3
	Trans Roof	.0097	.0105	250	370	418	0.5	0.6
	Left Cor.	.0118	.0086	940	1,000	418	1.5	1.8
	Right Cor.	.0157	.0065	470	650	418	0.6	1.6
FJ-10	Vert.	.0071	.0060	2,620	2,420	1,240	7.0	6.3
	Hor.	.0042	.0022	1,520	960	2,520	6.8	6.8
	Trans Roof	.0136	.0103	2,320	1,950	1,880	3.2	3.0
	Left Cor.	.0130	.0064	3,900	3.150	1,880	5.7	7.7
	Right Cor.	.0128	.0089	4,300	4,340	1,880	6.3	7.6
FJ-11	Vert.	.0128	.0094	-----	-----	-----	---	---
	Hor.	.0092	.0059	-----	-----	-----	---	---

TABLE 3

DEFORMATION MODULI
(PSI x 10^6)
FROM PLATE BEARING TESTS

Test Site	Initial Deformation Modulus	Sustained Deformation Modulus 0-1000 psi	1000-2000 psi	2000-3000 psi	3000-4000 psi
1L	.48	1.26	2.16	5.05	4.33
2R	.57	--	4.33	5.05	--
3T	.88	3.78	15.1	--	--
4L	.40	0.76	1.12	--	--
4R	.64	1.78	6.05	--	30.3
5L	.96	1.44	2.75	3.03	1.59
5R	.79	1.01	4.33	4.33	4.32
6L	.65	2.33	4.33	6.05	7.56
6R	1.24	2.75	4.33	7.58	6.05
7L	.77	1.51	4.33	6.05	--
7R	.83	1.21	2.16	3.03	--
8T	--	2.16	--	--	--
9L	1.16	1.08	4.33	6.05	30.3
9R	.82	1.08	2.75	4.33	5.05
10L	3.10	2.52	10.1	6.05	3.37
10R	1.37	2.75	3.03	3.03	3.37
11L	3.06	5.05	6.05	7.56	4.33
11R	3.50	5.05	4.33	5.05	3.78
12L	2.06	2.75	6.05	5.05	6.05
12R	2.00	2.33	6.05	5.05	6.05
13T	2.05	3.03	7.56	10.1	--
14L	.99	2.52	3.03	5.05	1.89
14R	1.68	1.51	3.03	5.05	3.03
15L	.54	0.76	1.01	1.89	1.89
15R	.89	1.44	2.02	2.33	2.75
17L	.67	1.44	2.33	--	2.52
17R	.50	0.82	2.75	--	1.68
18R	.53	2.00	2.00	--	3.03

TABLE 4
EXTENSOMETER RESULTS
PROJECT "B"

Test Site	Bolt Loc.	Bolt No.	Length (feet)	Distance from face (inches)	Ave. Stress along bolt	Mass. Ext. Δ' (inches)	% of Δ measured	Δ (inches)	$\sigma = E\,\Delta/L$ (psi)
R2	L	1	4	10	$.60\sigma x$	.0087	(.60-.15)/.85 = 53%	.0164	2450
	L	2	2	13	$.41\sigma z$	-----	-----------------	-----	----
	T	3	2	22	$.25\sigma y$	.0033	(.25-.10)/.90 = 17%	.0194	5820
	T	4	4	23	$.40\sigma y$	.0014	(.40-.20)/.80 = 25%	.0056	840
	T	5	6	22	$.48\sigma y$	.0035	(.48-.30)/.70 = 26%	.0135	1350
	R	6	2	16	$.32\sigma x$	.0035	(.32-.10)/.90 = 24%	.0146	4380
	R	7	4	12	$.54\sigma x$	.0094	(.54-.15)/.85 = 46%	.0204	3060
R4	L	1	2	23	$.15\sigma x$	.0224	(.15-.10)/.90 = 6%	.3740	74800*
	L	2	4	26	$.30\sigma z$	.0215	(.30-.15)/.85 = 18%	.1195	11950*
	T	3	2	15	$.45\sigma y$	.0020	(.45-.10)/.90 = 39%	.0051	1530
	T	4	6	--	-----	.0030	-----------------	-----	----
	T	5	4	--	-----	-----	-----------------	-----	----
	R	6	4	27	$.30\sigma x$	.0009	(.30-.15)/.85 = 18%	.0050	750
	R	7	2	--	-----	-----	-----------------	-----	----
R6	L	1	4	17	$.45\sigma x$	.0045	(.45-.15)/.85 = 35%	.0129	1935
	L	2	2	14	$.40\sigma x$	.0202	(.40-.10)/. 90 = 33%	.0606	18180*
	T	3	4	17	$.50\sigma y$	.0068	(.50-.20)/.80 = 37%	.0184	2760
	T	4	6	--	-----	-----	-----------------	-----	----
	T	5	2	14	$.48\sigma y$	.0045	(.48-.10)/.90 = 42%	.0107	3210
	R	6	2	--	-----	-----	-----------------	-----	----
	R	7	4	14	$.50\sigma x$	.0120	(.50-.15)/.85 = 41%	.0293	4395

TABLE 4
EXTENSOMETER RESULTS
PROJECT "B"
(cont.)

Test Site	Bolt Loc.	Bolt No.	Length (feet)	Distance from face (inches)	Ave. Stress along bolt	Mass. Ext. Δ' (inches)	% of Δ measured	Δ (inches)	σ= E Δ/L (psi)
R8	L	1	2	19	.25σx	.0604	(.25-.10)/.90 = 17%	------	----
	L	2	4	21	.40σz	.0531	(.40-.15)/.85 = 29%	-----	----
	T	3	-	--	-----	-----	----------------	-----	----
	T	4	6	--	-----	-----	----------------	-----	----
	T	5	-	--	-----	-----	----------------	-----	----
	R	6	4	11	.56σz	.0543	(.56-.15)/.85 = 48%	-----	----
	R	7	2	25	.11σz	.0349	(.11-.10)/.90 = 1%	-----	----
R10	L	1	4	24	.35σx	.0050	(.35-.15)/.85 = 24%	.0208	3120
	L	2	2	20	.21σz	.0010	(.21-.10)/.90 = 12%	.0083	2490
	T	3	4	18	.49σy	.0050	(.49-.20)/.80 = 36%	.0139	2085
	T	4	6	18	.53σy	.0098	(.53-.30)/.70 = 36%	.0272	2720
	T	5	2	17	.39σy	.0028	(.39-.10)/.90 = 32%	.0088	2640
	R	6	2	22	.16σx	.0068	(.16-.10)/.90 = 7%	.0959	28770*
	R	7	4	23	.36σz	.0171	(.36-.15)/.85 = 25%	.0684	10260*

* Values disregarded in calculating stresses.

NOTE: L = Left hand tunnel wall;
R = Right hand tunnel wall;
T = Roof of Tunnel

obtained by testing specimens in the laboratory. The design was based primarily on the deformation modulus of the various rock types and the magnitude of the primary stress inherent in the rock, as determined by the field studies.

Reservoir Geology - Comprehensive exploratory work in the reservoir area was performed to determine the effects of raising the reservoir on the drainage of mines in the Metaline District. This extensive geologic background knowledge developed was useful in the design of the dam and powerhouse.

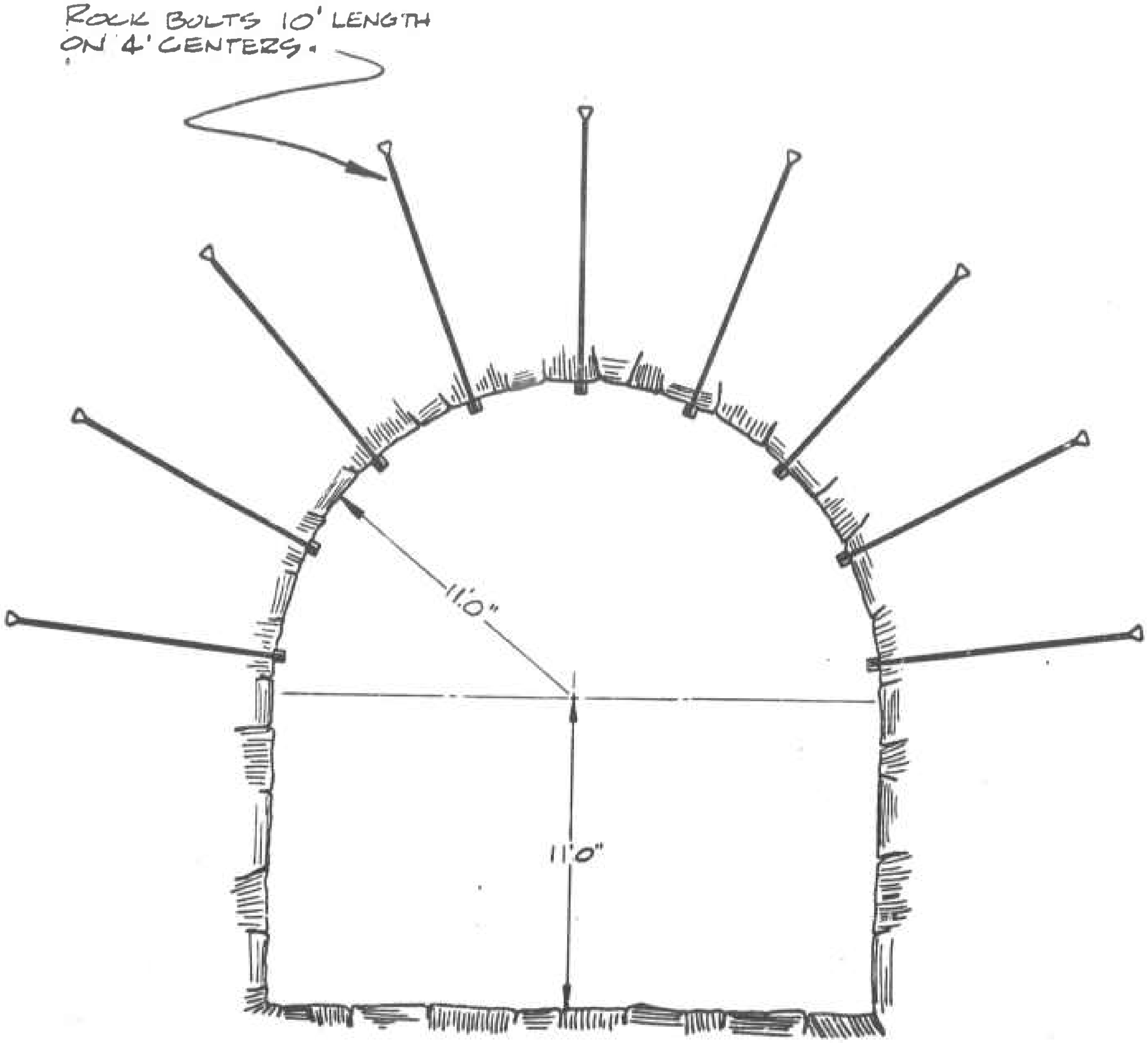
Tunnel Design

General Requirements - The underground structures consist of: 1) powerhouse access tunnel; 2) lower mucking tunnel; 3) powerhouse machine hall; 4) six intake tunnels; 5) intake gates and control gallery; 6) six penstocks; 7) dam access gallery 8) six draft tubes; 9) transformer bays and generator bus galleries; 10) diversion tunnel; for a total 8,690 linear feet and 460,000 cubic yards of underground excavation.

Powerhouse Access Tunnel and Mucking Tunnel - The powerhouse access tunnel design had to fulfill the requirements of mucking during powerhouse excavation as well as those of moving all of the generating equipment into the completed powerhouse. The alignment of the access tunnel, was arranged to allow the easiest possible access

for the powerhouse equipment at the portal. The tunnel was built normal to the natural slope at the portal and extended near the centerline but offset to the left of the center. Extra room for equipment maneuvering was provided at the turn by branching the lower mucking tunnel off at this point. The tunnel cross section, necessary to allow passage of the equipment and material, was a full arch with a radius of 11 feet and a height, invert to springline, of 11 feet, see Figure 5. For simplicity of site layout and efficient construction, this cross section was used for all access and mucking tunnels. According to the owner, support of the access and mucking tunnels was designed using the rock mass characteristics determined by the in situ rock testing program. A bolt length was selected based on "the zone of loosening" determined by extensometer tests and the pattern was chosen to conform with bolt length and joint spacing and produce a stressed beam around the opening. The typical minimum support was rock reinforcement by 10-foot grouted rock bolts on 4-foot centers in the tunnel arch, see Figure 5. Special bolting and gunite could be installed at the project Engineer's option.

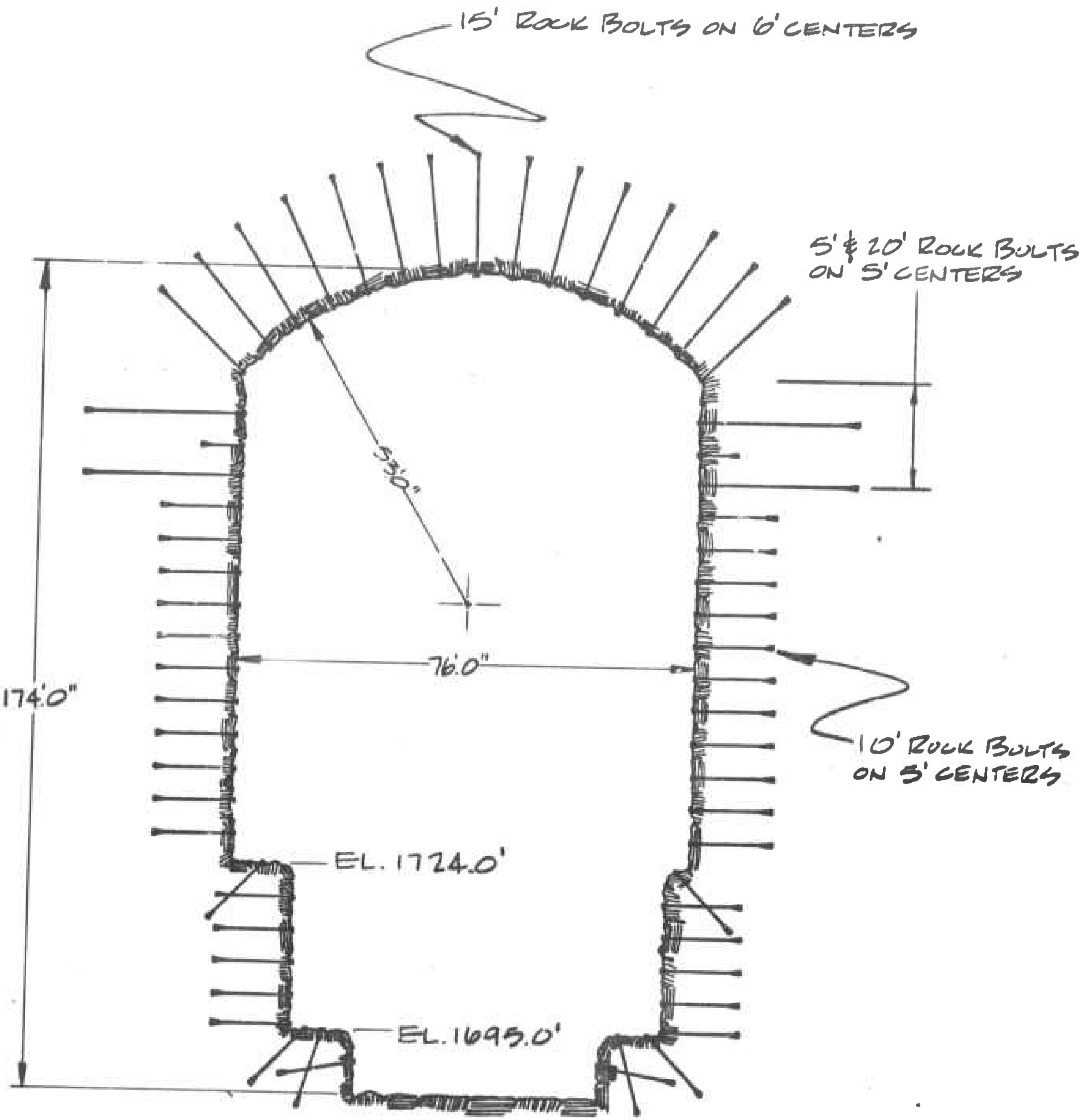
Machine Hall - The machine hall was designed with a total roof span of 76 feet and with an arch radius of 53 feet, see Figure 6. The arch cavity was supported with 15-foot grouted rock bolts on 6-foot spacings and covered with a gunite lining a minimum of 4 inches thick. In fracture zones and weak areas the pattern was closed to 5 feet or less. At the springline, and for a small distance below it, 20-foot grouted bolts were required at 5-foot spacings with supplemental



ACCESS AND MUCKING TUNNEL

SCALE: 1" = 6'0"

Figure 5.



MACHINE HALL ROCK REINFORCEMENT

NO SCALE

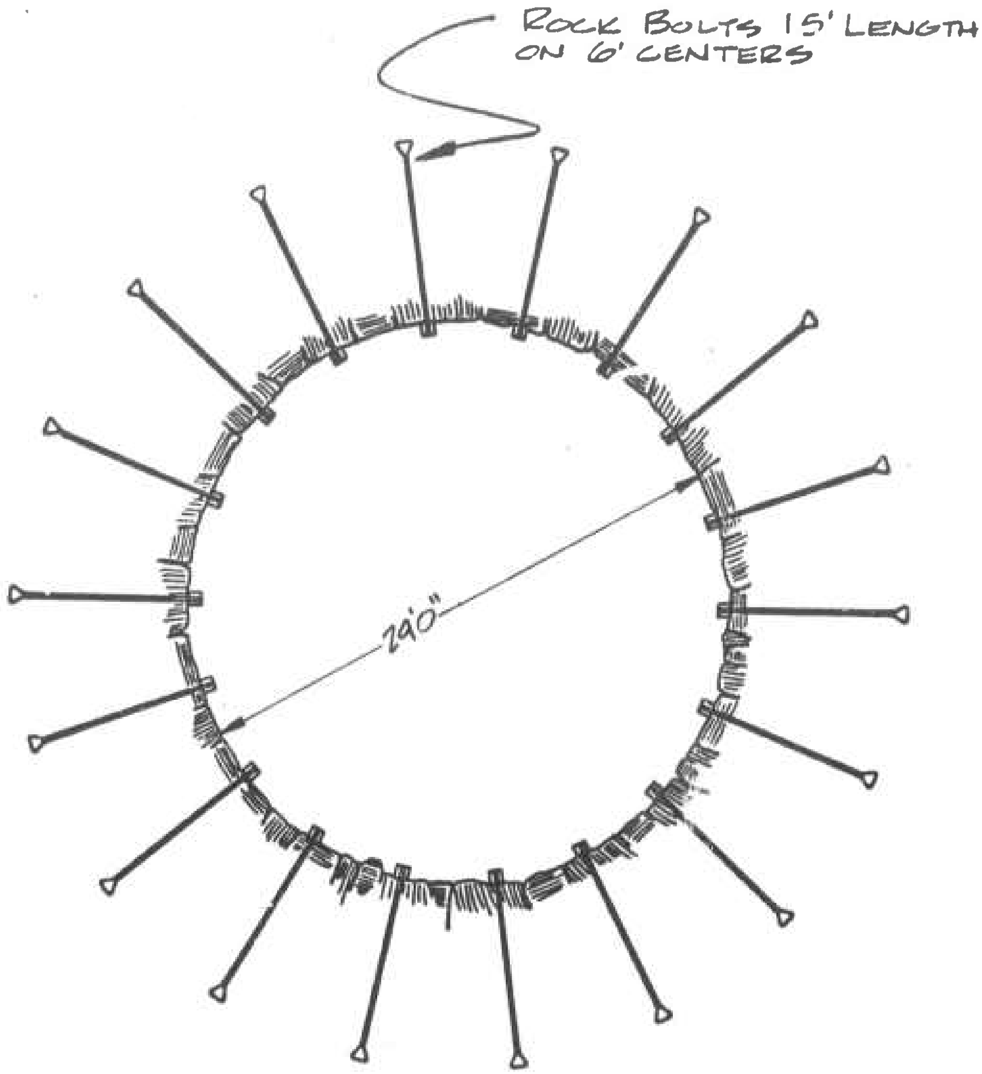
Figure 6.

5-foot grouted bolts installed equidistant between the long bolts. The side walls were reinforced with 10-foot grouted bolts on 5-foot centers. The benches left at elevation 1,724 and elevation 1,695 were reinforced with 45-degree down-angle bolts.

Penstock and Intake Tunnels - The penstocks and intake tunnels were designed as complementary units. The intake tunnels carry water at low pressure and velocity from the forebay excavation to the penstock intake gate. The penstocks carry the water at high velocity and pressure to the turbines. The spacing between the penstock tunnels is critical because a large spacing between tunnels requires a longer machine hall and a close spacing produces high stress concentrations. Because the rock surrounding the penstocks is required to help support the lining, it is imperative that the strength of the rock and the primary stress field be accurately assessed in order to space the penstocks at the minimum possible distance and with the minimum possible lining.

Penstock - The six penstocks are spaced 65 feet center to center and are 29-foot-diameter circular tunnels, see Figure 7. The rock was reinforced around the entire circumference of the vertical and lower horizontal runs while in the upper horizontal runs only the roof was reinforced. Typical reinforcement was 15-foot grouted rock bolts on 6-foot centers.

Intake Tunnels - The six intake tunnels were driven from a 22-foot wide mucking tunnel. The portals were constructed and



TYPICAL ROCK REINFORCEMENT FOR PENSTOCKS

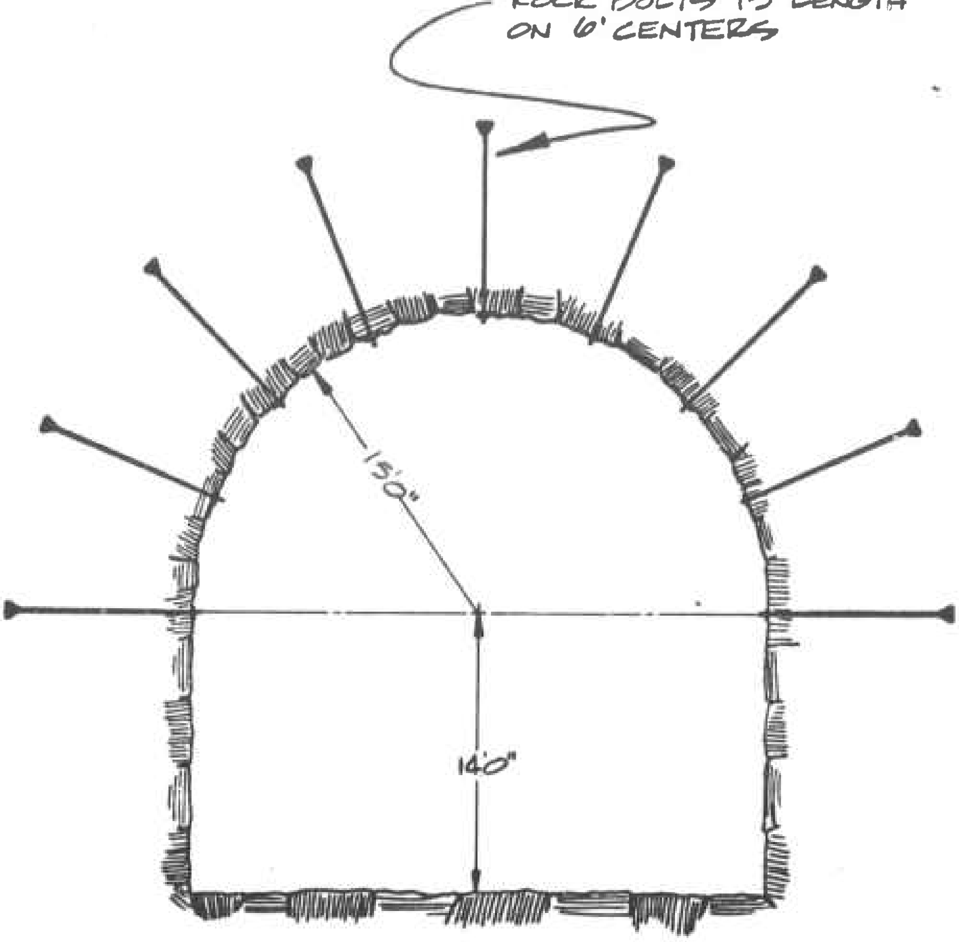
NO SCALE

Figure 7.

reinforced underground before the open forebay excavation was made. The intake tunnels are spaced on 56-foot centers. They are full arch with a 15-foot radius and a height, invert to springline, of 14 feet, Figure 8. Typical reinforcement consists of 15-foot grouted rock bolts on 6-foot centers in the arch.

Intake Gate Structure - The intake gate structure was designed as a vertical raise from the intake tunnel. The maximum height above the intake-tunnel invert is 147 feet. The gate slot is 38 feet wide and 14 feet deep. Access to the gate control chamber is by way of a 22-foot-wide gallery at elevation 2,005. The gate chamber was reinforced with 10-foot grouted bolts on 5-foot centers.

Access Gallery - The dam access gallery is a 22-foot-wide tunnel as shown in Figure 4. It was driven from a portal near the left abutment exploratory tunnel portal at an invert elevation of 1,790. It makes a 70-degree turn, with a 150-foot radius, from the portal to be parallel to the powerhouse centerline and 93 feet northeast of it. The invert is level for the length of the machine hall then it turns 11 degrees for 30 feet, with a 600-foot radius, and ascends at a 10-percent grade to the erosion cavity in the left abutment. The transformer bays open out from this gallery and the draft tube gate hoists are installed in it. A typical support consists of 10-foot grouted bolts on 4-foot centers.



TYPICAL ROCK REINFORCEMENT FOR INTAKE TUNNELS

SCALE: 1"=10'

Figure 8.

The generator bus galleries house the electric conductors between the generators and the transformer bays. They were designed as rectangular inclines, with a 40-percent grade and a 14 by 14-foot cross section, to elevation 1,768, then a vertical shaft 22 feet by $15\frac{1}{2}$ feet into the dam access gallery and the transformer bays. This design was later changed to allow arching of the roof with a radius of 15 feet 6 inches from the invert centerline. Typical support consists of 6-foot grouted bolts on 3-foot centers.

Transformer Bays - The transformer bays are daylighted to the face of the cliff above the after bay. The width of the bays is 36 feet and they have a full arch with a radius of 18 feet. The spring-line to invert distance varies from 4 feet to $18\frac{1}{2}$ feet. Support is by 15-foot grouted rock bolts on 5-foot centers. The transformer bays are spaced 65 feet center to center and leave rock pillars 29 feet wide between the daylighted bays. No stress relief problems developed in these pillars.

Draft Tubes - The draft tubes and control gates are on the generator centerline. The shape of the draft tubes is crucial to the hydraulic efficiency of the plant. The tube cross section is elliptical at the exit from the turbines. The tunnel at that point is a 46-foot-wide ellipse. The tunnel cross section undergoes steady transition to a full-arch cross section, then the height is increased to the after bay, Figure 9. Typical

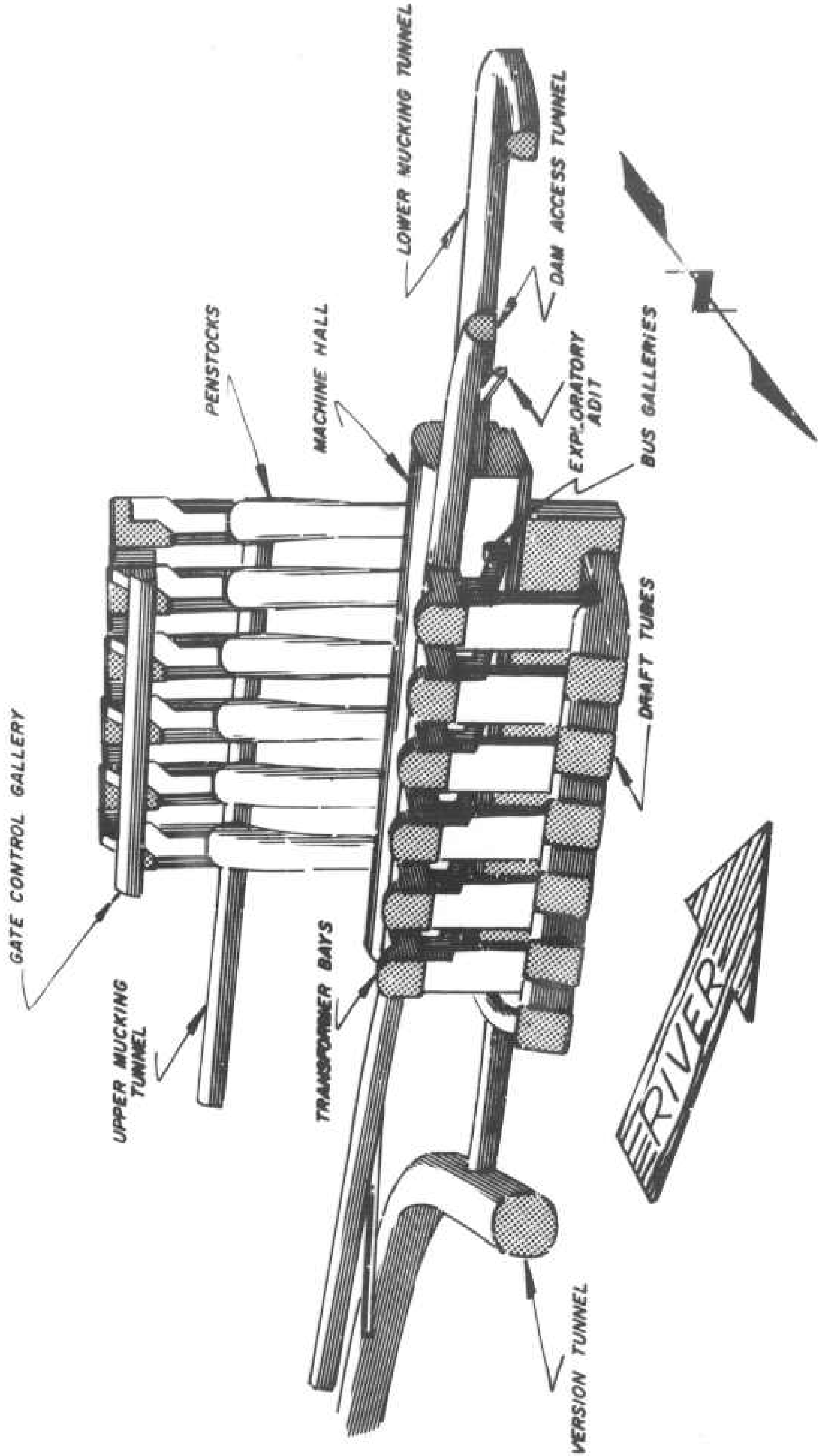

LOWER MUCKING TUNNEL
DAM ACCESS TUNNEL
PENSTOCKS
MACHINE HALL
EXPLORATORY ADIT
BUS GALLERIES
DRAFT TUBES
GATE CONTROL GALLERY
UPPER MUCKING TUNNEL
TRANSFORMER BAYS
RIVER
DIVERSION TUNNEL

Figure 9

support in the draft tubes consists of 20-foot grouted bolts on 8-foot centers. The pillars between the draft tubes are 25 feet thick. Stress problems which developed in these pillars are discussed on page 109.

Diversion Tunnel - The diversion tunnel is 910 feet long with a 42-foot horseshoe cross section. The exploratory program indicated that the tunnel would cross a faulted zone with closely fractured, weathered rhyolitic intrusive material along it. It was expected that this zone would require steel sets and lagging, so two typical sections were designed for the diversion tunnel. The section for competent rock was based on a 21-foot radius arch above the springline, and the sidewalls and invert were designed with a 42-foot radius of curvature. The roof was supported with 20-foot, non-grouted rock bolts on 8-foot centers. The gunite lining was installed outside the payline. The payline dimensions for the steel supported tunnel section in incompetent rock are the same. The steel and lagging are installed entirely outside the payline and then covered with gunite three inches deep over the ribs. The ribs were 8 WF 31. A total of thirty arch ribs, twenty side struts and ten invert struts were purchased. Spacing of the ribs was left to the Project Engineer during construction. Spacing varied from continuous to 10 feet.

A unique feature in the design of the diversion tunnel was the integration of the construction schedule of the dam with the river flow. The 42-foot-diameter lined tunnel would handle the river flow during the

summer and fall, but during the peak runoff the tunnel would reach its full capacity and the job site would be flooded. Rather than provide complete diversion, which would have required a second tunnel parallel to the first, the construction schedule was arranged in such a way that the dam foundation excavation would be completed and enough concrete in place that the flood would not cause any damage. Substantial savings were made by this approach, although a total estimate has never been completed.

Summary of Support Design - The typical rock bolt layout at the project site falls into three basic patterns: 1) 20-foot bolts in an 8-foot grid; 2) 15-foot bolts in a 6-foot grid; 3) 10-foot bolts in a 4-foot grid. Rock bolt specifications required 1-inch bolts with a minimum yield strength of 30,000 pounds.

If the rock bolts are tensioned to 90 percent yield strength, the 8-foot pattern will form a calculated zone of uniform compression 12 feet deep with a 2.3 psi uniform stress; the 6-foot pattern produced a 9-foot zone with a 4 psi uniform stress; the 4-foot pattern produced a zone 6 feet deep with a 9.1 psi uniform stress.

The 8-foot by 20-foot pattern was used in the diversion tunnel and in the draft tubes. Complete support by rock bolts in both structures apparently was not needed. The diversion tunnel was a temporary structure and the draft tubes are lined with steel and concrete. The other

rock bolting patterns are sufficiently tight so as to allow unlined or very lightly lined cross sections to be designed.

Construction

Machine Hall - In the course of excavating the roof arch in the machine hall, an adverse joint set was detected. To remedy this situation, supplementary rock reinforcement consisting of 30-foot-long bolts was installed. Closely fractured areas totaling approximately one-quarter of the roof area required additional application of a layer of gunite reinforced with wire mesh. The remainder of the roof was covered by wire mesh to prevent any falling rock fragments from endangering the workmen below. As excavation proceeded, it was decided that no rock bolting was required in the middle part of the side walls because the quality of the exposed rock was better than expected.

Draft Tubes -- While excavation for the draft tubes was in progress, a system of joints was revealed which presented a potential hazard. Therefore it was decided, as a precautionary measure, to introduce a prestressing force across the suspected slide surfaces. At each draft-tube pier, eight holes were drilled and tendons were installed, each consisting of ninety, 1/4-inch-diameter high-strength steel wires. Each tendon was prestressed to 636,000 pounds and the holes were grouted. This remedial correction was a force account item and cost in excess of $250,000.00.

Penstocks - Excavation of the penstocks uncovered a system of cavities which are located in a zone of weak rock and extend diagonally across all penstocks. To satisfy design requirements for the penstock lining, the following procedure was adopted. All loose and soft materials to a distance of 20 feet from the excavation line for the penstocks were removed and all cavities were backfilled with lean concrete. All voids detected during installation of a grout curtain across the intake area of the power plant were also grouted.

Diversion Tunnel - Construction of the 910-foot-long diversion tunnel, which was located in the left abutment of the dam, could not be excavated from each end as would be customary. A lawsuit, pending in the courts, restrained the owner and the contractor from occupying the lower portion of the river valley, including the portal sites for the diversion tunnel. It was therefore decided to excavate the tunnel from the inside, hoping that the legal arguments would be settled by the time portal excavation became imminent. The procedure of excavating the tunnel from within the mountain also eliminated the necessity of providing cofferdams at the portals.

While underground excavation for the power plant was underway in the rock mass adjacent to the left abutment, a 22-foot-diameter mucking tunnel was driven to intercept the diversion tunnel line downstream of the future plug, see Figure 4. Excavation of the 42-foot horseshoe section

proceeded in both directions using the heading-and-benching method of construction. In general, the rock encountered was competent limestone and dolomite requiring only rock bolts for stabilization of the roof arch. However, in the vicinity of the upstream portal, a zone of weathered rhyolitic porphyry was encountered as anticipated from exploratory holes, and advance through the soft and often clay-like formation was slow. The area was opened up by pilot drifts along both springlines before the top heading was excavated. Approximately 50 feet of this tunnel had to be supported by 8-inch-wide flange steel sets fitted with invert struts. Spacing was as required from continuous to 10 feet.

Blasting - In order to prevent excessive damage to surrounding rock, the need for carefully controlled blasting was recognized. During construction, the blast patterns and powder factors were developed by experimental means. Any given round was considered successful if 50 percent of the outside line of the trim holes could be traced on the tunnel surface. Wherever rock conditions permitted, the Contractor fired the trim rounds on the second delay. This was an effective application of pre-split blasting in the tunnel.

The length of the rounds was limited by the requirement that rock bolts be installed within three hours after blasting, and that they be installed within 5 feet of the working face. The length of the round was adjusted in such a way that mucking and bolting could be completed within the specified time depending on the equipment and labor available. The

maximum round was 15 feet and the minimum was 5 feet.

Evaluation

Use of the Exploratory Program - The geologic studies in conjunction with the rock mechanic studies were directly employed to establish design criteria and to definitely establish the suitability of the site for the proposed concrete arch dam and underground power plant. Although numerous faults and joints were found in the project areas, complete understanding of the geologic conditions allowed the designer to be confident that these apparent weaknesses would not seriously affect the structure.

The orientation of the power plant was the result of extensive studies involving alternate layouts. The machine hall excavation in its final orientation crosses most of the major joints at a steep angle. A minor adjustment to the orientation was made during final design to more closely parallel the cliff face and to move the machine hall out of the slightly cavernous dolomite at the southeast corner.

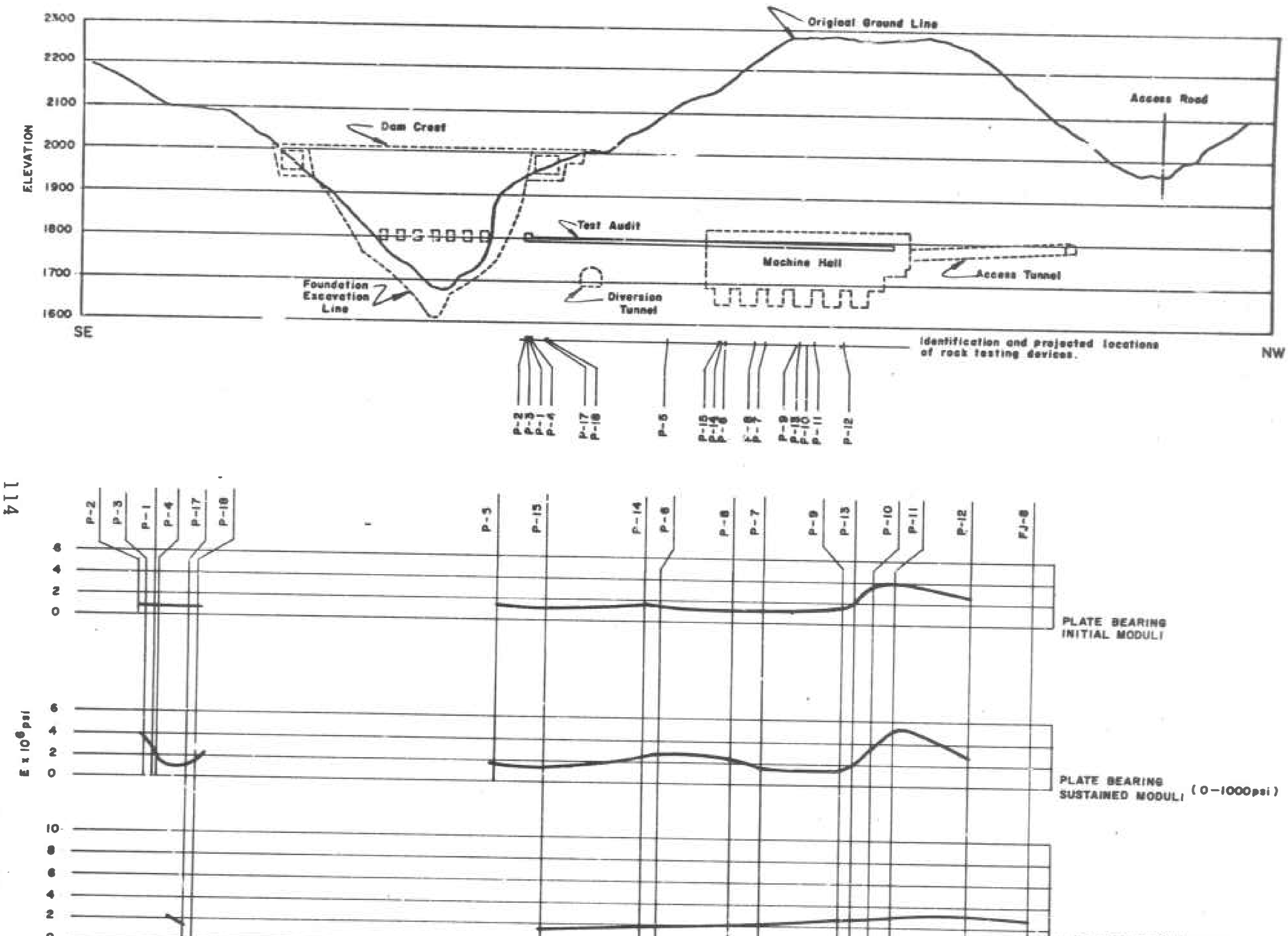
Water pump tests performed in conjunction with the drilling program aided in the design of the grout curtain beneath the dam and upstream of the powerhouse. The cavernous system encountered in the lower mucking tunnel, the penstocks, and the intake tunnels was not unknown, but the difficulty of grouting it was underestimated. The water flows and the extent of interconnection of the caverns were not properly interpreted

from the test borings and water pressure tests. Further borings could have aided in the proper.interpretation.

The geological conditions of the area, as revealed through the exploration program, indicated that the site was adequate for both the arch dam and the underground power plant. Information obtained during the early stages of the investigations called for a major redesign and relocation of the power plant. The initial layout of the powerhouse would have crossed the altered rhyolite zone. That material was an extreme problem in the diversion tunnel and the forebay excvation. Drilling detected the material and allowed the engineer to realign the project at an early stage.

Utilization of Rock Mechanics - Rock tests were conducted in the laboratory and in situ. The laboratory core samples were tested in compression, shear, tension and flexure; modulus of elasticity tests were made using sonic, compression, and flexure testing methods. In situ tests consisted of plate bearing tests, flat jack tests, and extensometer tests. These tests were utilized to obtain data on the deformation modulus, primary stress field, and to classify the rock.

Deformation Modulus - The deformation moduli obtained from plate bearing and flat jack tests were reduced to the same basis; that is, a pressure range from 0 to 1000 psi. The deformation moduli obtained by these methods were plotted on Figure 10 under a de-



PROJECTION OF EXPLORATORY TUNNEL
SHOWING DISTRIBUTION OF DEFORMATION MODULI OBTAINED FROM ROCK TESTS

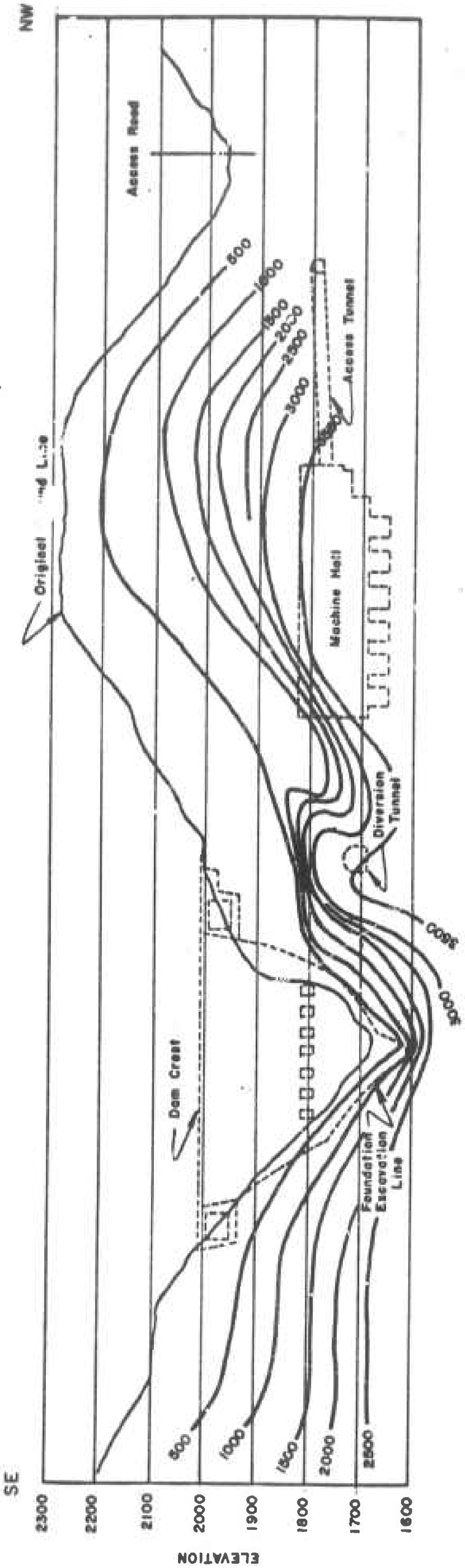
Figure 10

veloped profile of the site, and relatively good agreement between the values of neighboring sites became evident. With due consideration for the general geology of the project site and extrapolating to include the rock zones at the dam site, zones of constant deformation moduli could be satisfactorily determined, see Figure 11.

Primary Stress Field - A good indication of the primary stresses along the exploratory tunnel was obtained by the flat jack tests, and these values were somewhat confirmed by results from the relaxation tests. Based on these results, contours of equal pressures were drawn on profiles and sections through the powerhouse site with respective extrapolations for the dam site. Figures 11 and 12 show these contours as they were determined.

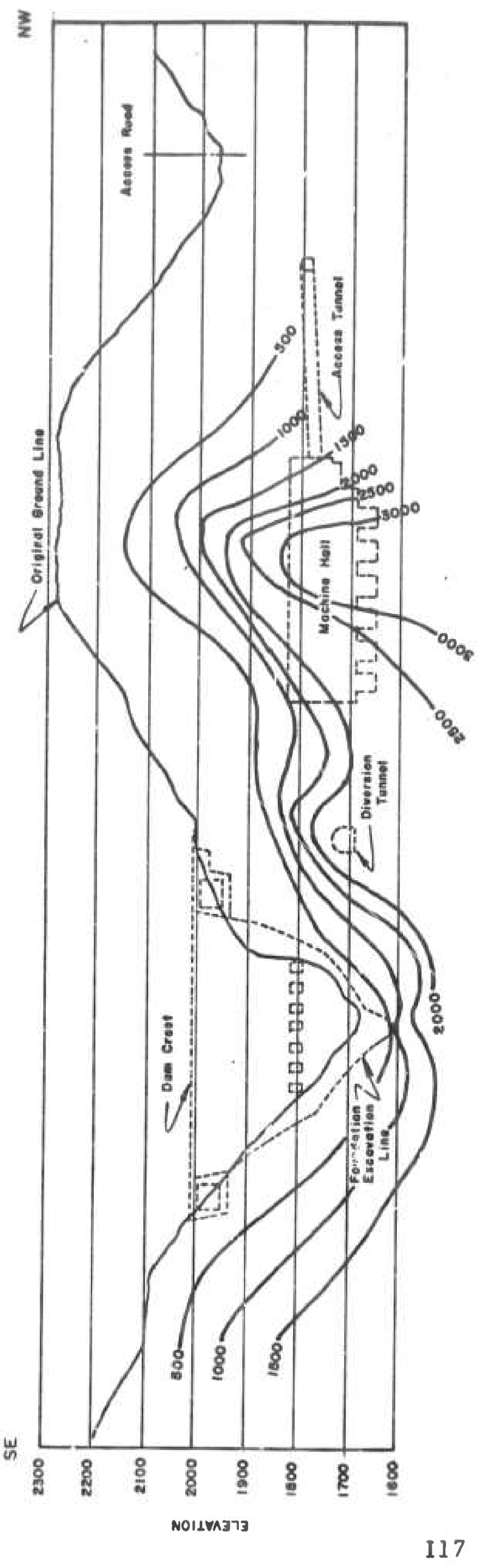
Rock Classification - The rock investigation results showed that a considerable variation in strength occurred between tests for one particular type of rock. Therefore, a system was introduced classifying the rock with respect to its structural strength rather than its chemical compostion and geologic origin. Based on the test results and observations during testing, strength criteria for four classes of rock were adopted for general guidance during the design and construction of the underground structures, Table 5.

It became obvious that local conditions and defects most influenced the structural strength of the rock at a specific location and the introduc-



DEVELOPED SECTION OF PROJECT SITE
VERTICAL ROCK STRESS DISTRIBUTION
(psi)

Figure 11



DEVELOPED SECTION OF PROJECT SITE
HORIZONTAL ROCK STRESS DISTRIBUTION
(psi)

Figure 12

TABLE 5. - COMPRESSIVE CRITERIA*

Class of Rock (1)	Unconfined Compression Ultimate (2)	Unconfined Compression Allowable (3)	Confined Compression Ultimate (4)	Confined Compression Allowable (5)
I	10,000	4,000	20,000	8,000
II	8,000	3,000	16,000	6,000
III	6,000	2,500	10,000	4,000
IV	4,000	1,500	8,000	3,000

*In pounds per square inch

TABLE 6. - VALUES FOR DEFORMATION MODULUS ASSIGNED TO VARIOUS CLASSES OF ROCK

Class of Rock (1)	Deformation Modulus, in million pounds per square inch: Permanent[1] (2)	Elastic[2] (3)	Total[3] (4)
I	10	4	3
II	4	4	2
III	2	2	1
IV	1	1	0.5

1 Permanent moduli were determined neglecting the initial portion of the loading curve.

2 Elastic moduli were determined using only the elastic deformation.

3 Total moduli were determined using total deformation.

tion of three values of rock-deformation moduli was considered necessary for the design of the project, and these values were assigned to the four classes of rock as shown in Table 6.

Comparison of Methods with State-of-the-Art Today - The design of the project cavities advanced the state-of-the-art when it was designed, but much has taken place since 1964. Today improvement could be made in design of support systems and lining and possibly improvement in opening orientation.

Support Systems - The recognition of the interplay between bolt length and spacing and the ability of the unit to form a stress beam for ground support was employed on the project. This theory, first advanced in the fifties, and while presently accepted, was not widely utilized in 1964. The design of the rock bolt system used at the project depended on experience factors. Currently there are methods which would allow the design of the bolt length and pattern utilizing stress, strength and geometric parameters (Raystown Project, 1970).

Lining Design - Today, lining design will allow the thickness of tunnel lining to be reduced when the modulus of elasticity and the Poisson's ratio for the rock through which the tunnel is to be built is known (Moody, 1964). For example, in a concrete-lined tunnel in a rock with a modulus similar to the concrete, the rock may be expected to take from 60 to 90 percent of the load. Even in weaker rocks where the

modulus is one-tenth of the concrete modulus, the rock may absorb 20 to 60 percent of the load.

Opening Orientation - More sophisticated analyses of flat jack data and other tests developed since 1964 would allow the determination of the principal stress field. This information can be utilized to align the major axes of the cavity openings parallel to the major primary stress, thus producing smaller stress concentrations surrounding the openings.

Monitoring of Completed Structures - A routine inspection and evaluation program was established as part of the operation of the project. Survey control monuments were established to allow a check on the absolute deflection of any part of the structure. Instrumentation, in the form of flat jacks and rock movement indicators, was installed in the machine-hall roof and walls, draft tubes and penstocks. The instruments, installed in areas where access would be unavailable during operation of the plant, were equipped with remote reading devices for monitoring during the life of the project. Mechanical type readout was provided for instruments installed along the centerline of the machine-hall roof. The remote reading instruments sense movement with variable linear inductance transducers, and are read at three stations located in the access gallery, main control room and on the overhead walkway.

The rock movement indicators are of two types. One type is a

tensioned and grouted hollow-core rock bolt. Through the hollow core is an aluminum rod, which is attached to the anchor and free to move relative to the head. The other type is a rod anchored at some depth and free to move relative to the rock surface. The flat jacks are sealed at a pressure near cancellation. Changes of pressure or pin location indicate build up of stresses.

Regular readout schedules have been observed, and the displacements have been plotted. Very frequent observations were made during construction and the initial operation of the project. Readout is currently scheduled for twice a year. Measured displacements have been within the limits established as safe prior to construction. To date, no attempt has been made to evaluate the design criteria from the recorded strains.

BIBLIOGRAPHY

Moody, W. T. "Importance of Geological Information as a Factor in Tunnel-Lining Design", Engineering Geology Case Histories Numbers 1 - 5. Prepared for the Division on Engineering Geology. The Geological Society of America, Inc., 1964.

Proctor, Robert V., and Thomas L. White. Rock Tunneling with Steel Supports. The Youngstown Printing Co., Youngstown, 1968.

Raystown Project Tunnel - Rock Mechanics Studies. Prepared for Department of the Army Baltimore District, Corps of Engineers. Foundation Sciences, Inc., 1970.

APPENDIX

APPENDIX

MAPS

Initial Form Letter
to Potential Data Sources

Dear

Foundation Sciences, Inc. has signed a contract with the U. S. Bureau of Mines to do a critical analysis study on all tunnels and chambers excavated in rock in Oregon and Washington. If the study produces practical results it will be expanded to the whole United States and eventually to other countries.

The purpose of the study is to provide an experience-based data bank on all factors which appear to have a significant bearing on (1) construction, (2) economics, (3) safety, (4) performance, and (5) maintenance of such underground excavation. The data bank will be computerized and made readily available to all data contributors, and summary reports on the project will be published at the time of its completion. It is hoped by both the U. S. Bureau of Mines and Foundation Sciences, Inc. that the data bank and reports will provide answers to the frequent vital questions raised by the various industries involved in this type of work.

A list of 75 organizations and companies involved with tunnel and chamber excavation work in Oregon and Washington has been compiled by us and the name of your firm has been included in it. We would be pleased if you could contribute to the program. If you can at this time or in the near future provide us with information of the kind shown on the enclosed questionnaire, would you please fill it out and return it to us in the enclosed self-addressed envelope.

Very truly yours,

FOUNDATION SCIENCES, INC.

R. Kenneth Dodds
President

Initial Contact Questionnaire

1. Has your firm or organization ever constructed, or had constructed for it, a tunnel, adit, or chamber greater than 10 feet in diameter?

2. Would you be willing to make the design and construction data of your tunnels, etc. available for our study and for the proposed data bank? If you are willing, any restrictions that you wish to impose will be honored.

3. If so, would you please indicate how many tunnels, adits, and chambers larger than 10 feet in diameter you have completed and/or have under construction.

4. If a firm other than yours did either the construction or the design work, would you please give us their name and address.

5. If you are willing to make the indicated data available, is it all in your files, in the other firm's files, or some in both? Would you please indicate which firm has what part of the data.

6. Can we make personal contact with you or another representative of your firm or organization as a follow-up on this query?

Agencies Replying To Initial Contact Letter

I. Federal, State, and County Organizations

Corps of Engineers
North Pacific Division
210 Custom House
Portland, Oregon 97209
Mr. Wm. Harold Stuart

Portland District
2850 S. E. 82nd Avenue
Portland, Oregon
Mr. D. H. Basgen

Seattle District
1519 Alaskan Way, S.
Seattle, Washington 98134
Mr. Edwin Derrick

Walla Walla District
City-County Airport
Walla Walla, Washington 99362
Col. Richard M. Connell

Bonneville Power and Light Administration
P. O. Box 3621
Portland, Oregon 97208
Mr. George S. Bingham

Bureau of Reclamation
Denver District
Denver Federal Center
Denver, Colorado 80225
Mr. B. P. Bellport

Boise District
P. O. Box 8008
Boise, Idaho 83707
Chief Engineer

II. Private, Municipal, and Co-op Organizations

City of Ashland
City Hall
Ashland, Oregon 97520
Mr. Allen A. Alsing

Central Lincoln Peoples Utility District
255 S. W. Coast Highway
Newport, Oregon 97365
Mr. John E. Schriner

Coos-Curry Electric Cooperative
P. O. Box 460
Coquille, Oregon 97423
Mr. Ray Shavere

Eugene Water and Electric Board
500 E. Fourth
Eugene, Oregon 97401
Mr. Herbert H. Hunt

Pacific Power and Light
920 S. W. 6th Avenue
Portland, Oregon 97204
Mr. Jack Stiles

Portland General Electric Company
621 S. W. Alder
Portland, Oregon 97204
Mr. Robert A. Blakeney

Portland Water Bureau
1800 S. W 6th Avenue
Portland, Oregon 97204
Mr. Ken Anderson

Chelan County PUD
327 North Wenatchee Avenue
Wenatchee, Washington 98801
Mr. E. C. Metcalf

Cowlitz County PUD
960 Commerce
Longview, Washington 98632
Mr. Carl H. Evans

Douglas County PUD
1151 North Main Street
East Wenatchee, Washington 98801
Mr. John A. Gregg

Franklin County PUD
1411 West Clark Street
Pasco, Washington 99302
Mr. Harold Haake

Grant County PUD
P. O. Box 878
Ephrata, Washington 98823
Mr. R. R. Ries

Mason County PUD No. 3
P. O. Box 490
Shelton, Washington 98594
Mr. Richard L. Thompson

Seattle City and Light Company
1015 Third Avenue
Seattle, Washington 98104
Mr. C. R. Hoidal

Skagit County PUD
313 Kincaid Street
Mt. Vernon, Washington 98273
Mr. Robert A. Yale

City of Tacoma PUD
P. O. Box 11007
Tacoma, Washington 98411
Mr. Carl E. Heenan

The Washington Water Power Company
P. O. Drawer 1445
Spokane, Washington 99210
Mr. R. H. Benker

Washington Public Power Supply Company
130 Vista Way
Kennewick, Washington 99336
Mr. S. K. Billingsley

III. Highway Departments and Railroads

Oregon State Highway Department
State Highway Building
Salem, Oregon 97310
Mr. Tom Edwards

Washington State Highway Department
Highway License Building
Olympia, Washington 98501
Mr. Larry Robertson

Burlington Northern Railroad Company
American Bank Building
621 S. W. Morrison
Portland, Oregon 97204
Mr. H. F. Moy

Southern Pacific Railway Company
65 Market Street
San Franscisco, California 94105
Mr. H. M. Williamson

Union Pacific Railway Company
1460 Dodge Street
Room 1012
Omaha, Nebraska 68102
Mr. R. M. Brown

Second Form Letter
to Potential Data Sources

Re: Advanced Research Projects Agency, State-of-the-Art Review
Underground Projects; Initial Questionnaire

Dear

Thank you for you previous letter of response to the above-referenced questionnaire. To date, through similar responses, we have located more than 100 tunnels and chambers in the states of Oregon and Washington. We are now in the process of collecting Design Memoranda, Bidding Documents, Completion Reports, and subsequent Inspection or Performance Reports on these projects. At a later date, it may be of great assistance if we could see Construction Daily Shift Reports. Therefore, we would appreciate information on where they can be obtained.

In your response, you indicated tunneling projects of sufficient size and interest to be included in the detailed analysis for our study; therefore, we would like to have the above-listed reports in order to record pertinent data. All data supplied to us will be recorded here and returned promptly. The data will be handled statistically and no project will be specifically identified in our study report.

Thank you for your cooperation.

Respectfully yours,

FOUNDATION SCIENCES, INC.

Paul W. Howell
Project Scientist

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE I

NAME	OWNER	LOCATION
BLUE RIVER DAM DIV	COE PORTLAND	LANE ORE
COUGAR MAIN DIV	COE PORTLAND	LANE ORE
COUGAR PENSTOCK	COE PORTLAND	LANE ORE
COUGAR REG OUTLET	COE PORTLAND	LANE ORE
COUGAR RUSH CREEK	COE PORTLAND	LANE ORE
GREEN PETER DIV	COE PORTLAND	LINN ORE
BIG CLIFF DIV	COE PORTLAND	LINN ORE
DETROIT DAM DIV	COE PORTLAND	MARION ORE
EAGLE GORGE OUTLET	COE SEATTLE	UNKNOWN
HANSON DAM OUTLET	COE SEATTLE	KING WASH
MUD MOUNTAIN 23D	COE SEATTLE	PIERCE WASH
MUD MOUNTAIN 9D	COE SEATTLE	PIERCE WASH
DWORSHAK DAM DIV	COE WALLA WALLA	BONNER IDA
LUCKY PEAK OUTLET	COE WALLA WALLA	BONNER IDA
CARMEN-SMITH POWER	EUG WAT & ELEC BD	LANE ORE
CARMEN DIV	EUG WAT & ELEC BD	LANE ORE
KNOWLES CREEK	ORE STATE HIWAY	LANE ORE
SUNSET	ORE STATE HIWAY	TILLAMOOK ORE
TOOTH ROCK	ORE STATE HIWAY	MULTNOMAH ORE
ELK CREEK	ORE STATE HIWAY	DOUGLAS ORE
CAPE CREEK	ORE STATE HIWAY	LANE ORE
ARCH CAPE	ORE STATE HIWAY	CLATSOP ORE
VISTA RIDGE WEST	ORE STATE HIWAY	MULTNOMAH ORE
VISTA RIDGE EAST	ORE STATE HIWAY	MULTNOMAH ORE
J C BOYLE PROJECT	PAC POWER & LIGHT	UNKNOWN
TOKETEE PROJECT	PAC POWER & LIGHT	UNKNOWN
SWIFT TUNNEL	PAC POWER & LIGHT	UNKNOWN
FARADAY DIV	PORTLAND GE	CLACKAMAS ORE
OAK GROVE	PORTLAND G E	CLACKAMAS ORE
OAK GROVE #2	PORTLAND GE	CLACKAMAS ORE
OAK GROVE #3	PORTLAND G E	CLACKAMAS ORE
ROUND BUTTE POWER	PORTLAND GE	JEFFERSON ORE
ROUND BUTTE DIV	PORTLAND G E	JEFFERSON ORE
ROUND BUTTE SPILL	PORTLAND G E	JEFFERSON ORE
ROUND BUTTE LL GRT	PORTLAND GE	JEFFERSON ORE
ROUND BUTTE LL ACC	PORTLAND G E	JEFFERSON ORE
ROUND BUTTE UL GRT	PORTLAND G E	JEFFERSON ORE
ROUND BUTTE UL ACC	PORTLAND G E	JEFFERSON ORE
ROUND BUTTE LR GRT	PORTLAND G E	JEFFERSON ORE
ROUND BUTTE UR ACC	PORTLAND G E	JEFFERSON ORE
ROUND BUTTE UR GRT	PORTLAND G E	JEFFERSON ORE
BULL RUN #0	PORTLAND GE	CLACKAMAS ORE

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE I

NAME	OWNER	LOCATION
BULL RUN #1	PORTLAND G E	CLACKAMAS ORE
BULL RUN #2	PORTLAND GE	CLACKAMAS ORE
BULL RUN #4	PORTLAND G E	CLACKAMAS ORE
ROUND BUTTE LR ACC	PORTLAND G E	JEFFERSON ORE
BULL RUN DIV	PORTLAND WATER BUR	CLACKAMAS ORE
BULL RUN LEFT ABT	PORTLAND WATER BUR	CLACKAMAS ORE
CAS#4 ABERNETHY	SP TRANSP CO	LANE ORE
CAS#16 FIELDS	SP TRANSP CO	LANE ORE
CAS#17 FIELDS	SP TRANSP CO	LANE ORE
CAS#11 FRAZIER	SP TRANSP CO	LANE ORE
CAS#12 FRAZIER	SP TRANSP CO	LANE ORE
CAS#13 FRAZIER	SP TRANSP CO	LANE ORE
CAS#14 FRAZIER	SP TRANSP CO	LANE ORE
CAS#23 LOOKOUT	SP TRANSP CO	LANE ORE
CAS#24 LOOKOUT	SP TRANSP CO	LANE ORE
CAS#21 MCCREDIE	SP TRANSP CO	LANE ORE
CAS#22 WESTFIR	SP TRANSP CO	LANE ORE
CAS#3 CASCADE SUMT	SP TRANSP CO	LANE ORE
CAS#18 WICOPEE	SP TRANSP CO	LANE ORE
CAS#19 WICOPEE	SP TRANSP CO	LANE ORE
CAS#20 WICOPEE	SP TRANSP CO	LANE ORE
COOS#16 CANARY	SP TRANSP CO	LANE ORE
COOS#15 CUSHMAN	SP TRANSP CO	LANE ORE
COOS#14 RICHARDSON	SP TRANSP CO	LANE ORE
COOS#17 KROLL	SP TRANSP CO	DOUGLAS ORE
COOS#18 KROLL	SP TRANSP CO	DOUGLAS ORE
COOS#19 REEDSPORT	SP TRANSP CO	DOUGLAS ORE
COOS#20 LAKESIDE	SP TRANSP CO	COOS ORE
CAS#5 CRUZATTE	SP TRANSP CO	LANE ORE
COOS#21 LAKESIDE	SP TRANSP CO	COOS ORE
COOS#13 VAUGHN	SP TRANSP CO	LANE ORE
SIS#1 CORNUTT	SP TRANSP CO	DOUGLAS ORE
SIS#2 GLENDALE	SP TRANSP CO	DOUGLAS ORE
SIS#3 GLENDALE	SP TRANSP CO	DOUGLAS ORE
SIS#4 GLENDALE	SP TRANSP CO	DOUGLAS ORE
SIS#5 GLENDALE	SP TRANSP CO	DOUGLAS ORE
SIS#6 GLENDALE	SP TRANSP CO	DOUGLAS ORE
SIS#7 GLENDALE	SP TRANSP CO	DOUGLAS ORE
SIS#9 HUGO	SP TRANSP CO	JOSEPHINE ORE
CAS#6 CRUZATTE	SP TRANSP CO	LANE ORE
SIS#8 WOLFCREEK	SP TRANSP CO	JOSEPHINE ORE
SIS#13 SISKIYOU	SP TRANSP CO	JOSEPHINE ORE

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE I

NAME	OWNER	LOCATION
SIS#14 SISKIYOU	SP TRANSP CO	JACKSON ORE
SIS#15 SISKIYOU	SP TRANSP CO	JACKSON ORE
TIL#26 COCHRAN	SP TRANSP CO	WASHINGTON ORE
TIL#27 COCHRAN	SP TRANSP CO	WASHINGTON ORE
TIL#28 ENRIGHT	SP TRANSP CO	TILLAMOOK ORE
TIL#29 ENRIGHT	SP TRANSP CO	TILLAMOOK ORE
TIL#30 ENRIGHT	SP TRANSP CO	TILLAMOOK ORE
TIL#32 ENRIGHT	SP TRANSP CO	TILLAMOOK ORE
CAS#7 CRUZATTE	SP TRANSP CO	LANE ORE
TIL#34 ENRIGHT	SP TRANSP CO	TILLAMOOK ORE
TIL#35 ENRIGHT	SP TRANSP CO	TILLAMOOK ORE
TIL#36 ENRIGHT	SP TRANSP CO	TILLAMOOK ORE
TIL#25 TIMBER	SP TRANSP CO	WASHINGTON ORE
TOL#24 EDDYVILLE	SP TRANSP CO	LINCOLN ORE
JEF#38 WILSONIA	SP TRANSP CO	MULTNOMAH ORE
CAS#8 CRUZATTE	SP TRANSP CO	LANE ORE
CAS#9 CRUZATTE	SP TRANSP CO	LANE ORE
CAS#10 CRUZATTE	SP TRANSP CO	LANE ORE
CAS#15 FIELDS	SP TRANSP CO	LANE ORE
MAYFIELD POWER	CITY OF TACOMA	LEWIS WASH
MAYFIELD DIV	CITY OF TACOMA	LEWIS WA
MOSSY ROCK DIV #1	CITY OF TACOMA	LEWIS WASH
MAYFIELD DIV #2	CITY OF TACOMA	LEWIS WASH
LA GRANDE POWER	CITY OF TACOMA	THURSTON WASH
CUSHMAN #2	CITY OF TACOMA	MASON WASH
CUSHMAN DIV	CITY OF TACOMA	MASON WASH
PORT-HUNNING #1	UNION PACIFIC RR	MULTNOMAH ORE
PORT-SPOK #12	UNION PACIFIC RR	WHITMAN WA
PORT-SPOK #13	UNION PACIFIC RR	WHITMAN WA
PORT-SPOK #14	UNION PACIFIC RR	WHITMAN WA
PORT-SPOK #15	UNION PACIFIC RR	WHITMAN WA
PORT-SPOK #16	UNION PACIFIC RR	ADAMS WA
PORT-SPOK #17	UNION PACIFIC RR	ADAMS WA
OLYMPIA BR MP 5.23	UNION PACIFIC RR	THURSTON WA
OLYMPIA BR MP 5.76	UNION PACIFIC RR	THURSTON WA
ORE EAST BR #16	UNION PACIFIC RR	MALHEUR ORE
ORE EAST BR #17	UNION PACIFIC RR	UNKNOWN
PORT-HUNNING #1.25	UNION PACIFIC RR	MULTNOHAH OR
PORT-HUNNING #1.50	UNION PACIFIC RR	HOODRIVER OR
PORT-HUNNING #3.50	UNION PACIFIC RR	UMATILLA OR
PORT-HUNNING #6	UNION PACIFIC RR	BAKER OR
PORT-SEA MP 4.50	UNION PACIFIC RR	MULTNOMAH OR

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE I

NAME	OWNER	LOCATION
PORT-SPOK #7	UNION PACIFIC RR	WALLA WALLA WA
PORT-SPOK #10	UNION PACIFIC RR	WHITMAN WA
PORT-SPOK #11	UNION PACIFIC RR	WHITMAN WA
2/108 TUNNEL #1	WASH HWY DEPT	CHELAN WASH
14/216	WASH HWY DEPT	UNKNOWN
20/108	WASH HWY DEPT	CHELAN WASH
20/111	WASH HWY DEPT	CHELAN WASH
20/113N	WASH HWY DEPT	CHELAN WASH
97/24 MT BAKER	WASH HWY DEPT	UNKNOWN
97/359 KNAPPS HILL	WASH HWY DEPT	UNKNOWN
101/23 FORT COL	WASH HWY DEPT	UNKNOWN
123/106	WASH HWY DEPT	UNKNOWN
12/308 RIMROCK	WASH HWY DEPT	YAKIMA WASH
14/128 TUNNEL #1	WASH HWY DEPT	UNKNOWN
14/129 TUNNEL #2	WASH HWY DEPT	UNKNOWN
14/130 TUNNEL #3	WASH HWY DEPT	UNKNOWN
14/133 TUNNEL #4	WASH HWY DEPT	UNKNOWN
14/134 TUNNEL #5	WASH HWY DEPT	UNKNOWN
14/215	WASH HWY DEPT	UNKNOWN
YAKIMA MAIN CANAL	BU REC BOISE	KITTITAS ORE
KLAMATH CANAL A	BU REC BOISE	KLAMATH ORE
BLACK CANYON T#1	BU REC BOISE	GEM IDA
BLACK CANYON T#2	BU REC BOISE	GEM IDA
BLACK CANYON T#2A	BU REC BOISE	GEM IDA
BLACK CANYON T#3	BU REC BOISE	GEM IDA
BLACK CANYON T#4	BU REC BOISE	GEM IDA
BLACK CANYON T#5	BU REC BOISE	GEM IDA
BLACK CANYON T#6	BU REC BOISE	GEM IDA
BLACK CANYON T#7	BU REC BOISE	GEM IDA
BLACK CANYON T#8	BU REC BOISE	GEM IDA
COLU BASIN BACON	BU REC BOISE	UNKNOWN
FRENCHMAN HILLS	BU REC BOISE	UNKNOWN
SNOW LAKE	BU REC BOISE	UNKNOWN
DESCHUTES T#1	BU REC BOISE	WASCO ORE
DESCHUTES T#2	BU REC BOISE	WASCO ORE
OWHYEE APPRH N CAN	BU REC BOISE	MALHEUR ORE
OWYHEE LATRL N CAN	BU REC BOISE	MALHEUR ORE
OWYHEE T#1 N CAN	BU REC BOISE	MALHEUR ORE
OWYHEE T#3 N CAN	BU REC BOISE	MALHEUR ORE
OWYHEE T#4 N CAN	BU REC BOISE	MALHEUR ORE
OWYHEE T#5 S CAN	BU REC BOISE	MALHEURORE
OWYHEE T#6 X CAN	BU REC BOISE	MALHEUR ORE

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE I

NAME	OWNER	LOCATION
OWYHEE T#7 S CAN	BU REC BOISE	MALHEUR ORE
ROGUE RIV CAS DIV	BU REC BOISE	KLAMATH ORE
ROGUE RIV S FORK	BU REC BOISE	JACKSON ORE
ROGUE RIV G S POWR	BU REC BOISE	JACKSON ORE
VALE T#1	BU REC BOISE	MALHEUR ORE
VALE T#2	BU REC BOISE	MALHEUR ORE
VALE T#3	BU REC BOISE	MALHEUR ORE
VALE T#4	BU REC BOISE	MALHEUR ORE
VALE T#5	BU REC BOISE	MALHEUR ORE
YAKIMA KITTITAS MC	BU REC BOISE	KITTITAS WASH
T#2 S BRANCH CANAL	BU REC BOISE	KITTITAS WASH
ROZA DIV	BU REC BOISE	KITTITAS ORE
T#3 YAKIMA RIDGE	BU REC BOISE	KITTITAS ORE
T#5 YAKIMA RIDGE	BU REC BOISE	KITTITAS ORE
T#7 YAKIMA RIDGE	BU REC BOISE	KITTITAS ORE
T#8 YAKIMA RIDGE	BU REC BOISE	KITTITAS ORE
YAKIMA PROJECT	BU REC BOISE	KITTITAS, WASH
YAKIMA ROCKY POINT	BU REC BOISE	KITTITAS ORE
YAKIMA RIVER	BU REC BOISE	KITTITAS ORE
T#1 N BRANCH CANAL	BU REC BOISE	KITTITAS ORE
T#2 N BRANCH CANAL	BU REC BOISE	KITTITAS ORE
T#3 N BRANCH CANAL	BU REC BOISE	KITTITAS ORE
T#4 N BRANCH CANAL	BU REC BOISE	KITTITAS ORE
T#5 N BRANCH CANAL	BU REC BOISE	KITTITAS ORE
T#1 S BRANCH CANAL	BU REC BOISE	KITTITAS ORE
PRINEVILLE U/S DIV	BU REC BOISE	CROOK ORE
PRINEVILLE D/S DIV	BU REC BOISE	COOK ORE
KLAMATH CANAL A	BU OF REC BOISE	KLAMATH OR
BLUE SLIDE	BURLINGTON RR	WASHINGTON
PALISADES	BURLINGTON RR	WASHINGTON
ROCKLAKE #43	BURLINGTON RR	WASHINGTON
WATTS #41	BURLINGTON RR	WASHINGTON
.2 MII E SPOKANE	BURLINGTON RR	WASHINGTON
EASTON	BURLINGTON RR	WASHINGTON
WHITTIER	BURLINGTON RR	WASHINGTON
JOHNSON CR #45	BURLINGTON RR	WASHINGTON
FASTON	BURLINGTON RR	WASHINGTON
HORLICK #2	BURLINGTON RR	WASHINGTON
HORLICK #2	BURLINGTON RR	WASHINGTON
TANCUM	BURLINGTON RR	WASHINGTON
SNDQUALMIE #50	BURLINGTON RR	WASHINGTON
VAIL	BURLINGTON RR	WASHINGTON

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE I

NAME	OWNER	LOCATION
WOLF CREEK	BURLINGTON RR	WASHINGTON
CAPE HORN #1	BURLINGTON NORTH	CAPE HORN WASH
CAPE HORN #10	BURLINGTON NORTH	KLICKITAT WASH
CAPE HORN #11	BURLINGTON NORTH	KLICKITAT WASH
CAPE HORN #12	BURLINGTON NORTH	KLICKITAT WASH
CAPE HORN #13	BURLINGTON NORTH	FRANKLIN WASH
CAPE HORN #15	BURLINGTON NORTH	FRANKLIN WASH
CAPE HORN #16	BURLINGTON NORTH	FRANKLIN WASH
CAPE HORN #17	BURLINGTON NORTH	FRANKLIN WASH
CAPE HORN #18	BURLINGTON NORTH	WHITMAN WASH
FORT WRIGHT #19	BURLINGTON NORTH	SPOKANE WASH
O T RY #1	BURLINGTON NORTH	WASCO ORE
CAPE HORN #2	BURLINGTON NORTH	SKAMANIA WASH
O T RY #2	BURLINGTON NORTH	WASCO ORE
O T RY #3	BURLINGTON NORTH	WASCO ORE
O T RY #4	BURLINGTON NORTH	WASCO ORE
GATEWAY #5	BURLINGTON NORTH	JEFFERSON ORE
MAYGER #3	BURLINGTON NORTH	COLUMBIA ORE
CORNELIUS	BURLINGTON NORTH	MULTNOMAH ORE
CAPE HORN #3	BURLINGTON NORTH	SKAMANIA WASH
CASCADE	BURLINGTON RR	WASHINGTON
EVERETT #15	BURLINGTON RR	WASHINGTON
OROVILLE #7	BURLINGTON RR	WASHINGTON
SAMISH #18	BURLINGTON RR	WASHINGTON
SEATTLE #17	BURLINGTON RR	WASHINGTON
WINSTON #14	BURLINGTON RR	WASHINGTON
STAMPEDE #1	BURLINGTON RR	WASHINGTON
STAMPEDE #4	BURLINGTON RR	WASHINGTON
CAPE HORN #4	BURLINGTON NORTH	SKAMANIA WASH
OSTRANDER	BURLINGTON RR	WASHINGTON
NELSON-BENNETT	BURLINGTON RR	WASHINGTON
RUSTON	BURLINGTON RR	WASHINGTON
CAPE HORN #5	BURLINGTON NORTH	SKAMANIA WASH
CAPE HORN #6	BURLINGTON NORTH	SKAMANIA WASH
CAPE HORN #7	BURLINGTON NORTH	KLICKITAT WASH
CAPE HORN #8	BURLINGTON NORTH	KLICKITAT WASH
CAPE HORN #9	BURLINGTON NORTH	KLICKITAT WASH

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE II

NAME	ENGINEER	CONTRACTOR
BLUE RIVER DAM DIV	COE PORTLAND	RADCO & AUSUM CONS
COUGAR MAIN DIV	COE PORTLAND	NORTHWOOD INC
COUGAR PENSTOCK	COE PORTLAND	BELEMONT CONST INC
COUGAR REG OUTLET	COE PORTLAND	BELMONT CONST INC
COUGAR RUSH CREEK	COE PORTLAND	BELMONT CONST INC
GREEN PETER DIV	COE PORTLAND	PAUL HARDEM AN INC
BIG CLIFF DIV	COE PORTLAND	CONSOLIDATED BLDS
DETROIT DAM DIV	COE PORTLAND	UNKNOWN
EAGLE GORGE OUTLET	COE SEATTLE	UNKNOWN
HANSON DAM OUTLET	COE SEATTLE	UNKNOWN
MUD MOUNTAIN 23D	COE SEATTLE	UNKNOWN
MUD MOUNTAIN 9D	COE SEATTLE	UNKNOWN
DWORSHAK DAM DIV	COE WALLA WALLA	PETER KIEWITT
LUCKY PEAK OUTLET	COE WALLA WALLA	UNKNOWN
CARMEN-SMITH POWER	BECHTEL	UNKNOWN
CARMEN DIV	BECHTEL	UNKNOWN
KNOWLES CREEK	ORE STATE HIWAY	GIBBONS & REED
SUNSET	ORE STATE HIWAY	KERNS & KIBBE
TOOTH ROCK	UNKNOWN	UNKNOWN
ELK CREEK	ORE STATE HIWAY	UNKNOWN
CAPE CREEK	ORE STATE HIWAY	UNKNOWN
ARCH CAPE	ORE STATE HIWAY	UNKNOWN
VISTA RIDGE WEST	ORE STATE HIWAY	DRAKE-WINSTON
VISTA RIDGE EAST	ORE STATE HIWAY	DRAKE-WINSTON
J C BOYLE PROJECT	PIONEER SERV & ENG	MORRISON & KNUDSEN
TOKETEE PROJECT	PIONEER SERV & ENG	L E DIXON
SWIFT TUNNEL	UNKNOWN	UNKNOWN
FARADAY DIV	EBASCO	G. F. ATKINSON
OAK GROVE	EBASCO	UNKNOWN
OAK GROVE #2	EBASCO	UNKNOWN
OAK GROVE #3	EBASCO	UNKNOWN
ROUND BUTTE POWER	BECHTEL	PETER KIEWITT
ROUND BUTTE DIV	BECHTEL	PETER KIEWITT
ROUND BUTTE SPILL	BECHTEL	PETER KIEWITT
ROUND BUTTE LL GRT	BECHTEL	PETER KIEWITT
ROUND BUTTE LL ACC	BECHTEL	PETER KIEWITT
ROUND BUTTE UL GRT	BECHTEL	PETER KIEWITT
ROUND BUTTE UL ACC	BECHTEL	PETER KIEWITT
ROUND BUTTE LR GRT	BECHTEL	PETER KIEWITT
ROUND BUTTE UR ACC	BECHTEL	PETER KIEWITT
ROUND BUTTE UR GRT	BECHTEL	PETER KIEWITT
BULL RUN #0	C. P. DUNN	UNKNOWN

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE II

NAME	ENGINEER	CONTRACTOR
BULL RUN #1	J. G. WHITE	UNKNOWN
BULL RUN #2	J. G. WHITE	UNKNOWN
BULL RUN #4	J. G. WHITE	UNKNOWN
ROUND BUTTE LR ACC	BECHTEL	PETER KIEWITT
BULL RUN DIV	STEVENS THOMPSON	GATES & FOX
BULL RUN LEFT ABT	STEVENS THOMPSON	GATES & FOX
CAS#4 ABERNETHY	SP TRANSP CO	UTAH CONSTR CO
CAS#16 FIELDS	SP TRANSP CO	UTAH CONSTR CO
CAS#17 FIELDS	SP TRANSP CO	UTAH CONSTR CO
CAS#11 FRAZIER	SP TRANSP CO	UTAH CONSTR CO
CAS#12 FRAZIER	SP TRANSP CO	UTAH CONSTR CO
CAS#13 FRAZIER	SP TRANSP CO	UTAH CONSTR CO
CAS#14 FRAZIER	SP TRANSP CO	UTAH CONSTR CO
CAS#23 LOOKOUT	SP TRANSP CO	SP TRANSP CO
CAS #23 LOOKOUT	SP TRANSP CO	SP TRANSP CO
CAS#21 MCCREDIE	SP TRANSP CO	UTAH CONSTR CO
CAS#22 WESTFIR	SP TRANSP CO	SP TRANSP CO
CAS#3 CASCADE SUMT	SP TRANSP CO	UTAH CONSTR CO
CAS#18 WICOPEE	SP TRANSP CO	UTAH CONSTR CO
CAS#19 WICOPEE	SP TRANSP CO	UTAH CONSTR CO
CAS#20 WICOPEE	SP TRANSP CO	UTAH CONSTR CO
COOS#16 CANARY	SP TRANSP CO	SP TRANSP CO
COOS#15 CUSHMAN	SP TRANSP CO	SP TRANSP CO
COOS#14 RICHARDSON	SP TRANSP CO	SP TRANSP CO
COOS#17 KROLL	SP TRANSP CO	SP TRANSP CO
COOS#18 KROLL	SP TRANSP CO	SP TRANSP CO
COOS#19 REEDSPORT	SP TRANSP CO	SP TRANSP CO
COOS#20 LAKESIDE	SP TRANSP CO	SP TRANSP CO
CAS#5 CRUZATTE	SP TRANSP CO	UTAH CONSTR CO
COOS#21 LAKESIDE	SP TRANSP CO	SP TRANSP CO
COOS#13 VAUGHN	SP TRANSP CO	SP TRANSP CO
SIS#1 CORNUTT	SP TRANSP CO	SP TRANSP CO
SIS#2 GLENDALE	SP TRANSP CO	SP TRANSP CO
SIS#3 GLENDALE	SP TRANSP CO	SP TRANSP CO
SIS#4 GLENDALE	SP TRANSP CO	SP TRANSP CO
SIS#5 GLENDALE	SP TRANSP CO	SP TRANSP CO
SIS#6 GLENDALE	SP TRANSP CO	SP TRANSP CO
SIS#7 GLENDALE	SP TRANSP CO	SP TRANSP CO
SIS#9 HUGO	SP TRANSP CO	SP TRANSP CO
CAS#6 CRUZATTE	SP TRANSP CO	UTAH CONSTR CO
SIS#8 WOLFCREEK	SP TRANSP CO	SP TRANSP CO
SIS#13 SISKIYOU	SP TRANSP CO	SP TRANSP CO

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE II

NAME	ENGINEER	CONTRACTOR
SIS#14 SISKIYOU	SP TRANSP CO	SP TRANSP CO
SIS#15 SISKIYOU	SP TRANSP CO	SP TRANSP CO
TIL#26 COCHRAN	SP TRANSP CO	SP TRANSP CO
TIL#27 COCHRAN	SP TRANSP CO	SP TRANSP CO
TIL#28 ENRIGHT	SP TRANSP CO	SP TRANSP CO
TIL#29 ENRIGHT	SP TRANSP CO	SP TRANSP CO
TIL#30 ENRIGHT	SP TRANSP CO	SP TRANSP CO
TIL#32 ENRIGHT	SP TRANSP CO	SP TRANSP CO
CAS#7 CRUZATTE	SP TRANSP CO	UTAH CONSTR CO
TIL#34 ENRIGHT	SP TRANSP CO	SP TRANSP CO
TIL#35 ENRIGHT	SP TRANSP CO	SP TRANSP CO
TIL#36 ENRIGHT	SP TRANSP CO	SP TRANSP CO
TIL#25 TIMBER	SP TRANSP CO	SP TRANSP CO
TOL#24 EDDYVILLE	SP TRANSP CO	SP TRANSP CO
JEF#38 WILSONIA	SP TRANSP CO	SP TRANSP CO
CAS#8 CRUZATTE	SP TRANSP CO	UTAH CONSTR CO
CAS#9 CRUZATTE	SP TRANSP CO	UTAH CONSTR CO
CAS#10 CRUZATTE	SP TRANSP CO	UTAH CONSTR CO
CAS#15 FIELDS	SP TRANSP CO	SP TRANSP CO
MAYFIELD POWER	CITY OF TACOMA	UNKNOWN
MAYFIELD DIV	HARZA ENGINEERING	ARUNDEL CORP
MOSSY ROCK DIV #1	HARZA ENGINEERING	UNKNOWN
MAYFIELD DIV #2	HARZA ENGINEERING	UNKNOWN
LA GRANDE POWER	UNKNOWN	L.E. DIXON CO
CUSHMAN #2	UNKNOWN	YOUDALL CONST
CUSHMAN DIV	CITY OF TACOMA	A GUTHRIE CO
PORT-HUNNING #1	UNION PACIFIC RR	UNION PACIFIC RR
PORT-SPOK #12	UNION PACIFIC RR	UNION PACIFIC RR
PORT-SPOK #13	UNION PACIFIC RR	UNION PACIFIC RR
PORT-SPOK #14	UNION PACIFIC RR	UNION PACIFIC RR
PORT-SPOK #15	UNION PACIFIC RR	UNION PACIFIC RR
PORT-SPOK #16	UNION PACIFIC RR	UNION PACIFIC RR
PORT-SPOK #17	UNION PACIFIC RR	UNION PACIFIC RR
OLYMPIA BR MP 5.23	UNION PACIFIC RR	UNION PACIFIC RR
OLYMPIA BR MP 5.76	UNION PACIFIC RR	UNION PACIFIC RR
ORE EAST BR #16	UNION PACIFIC RR	UNION PACIFIC RR
ORE EAST BR #17	UNION PACIFIC RR	UNION PACIFIC RR
PORT-HUNNING #1.25	COE PORTLAND	UNKNOWN
PORT-HUNNING #1.50	UNION PACIFIC RR	UNION PACIFIC RR
PORT-HUNNING #3.50	UNION PACIFIC RR	UNION PACIFIC RR
PORT-HUNNING #6	UNION PACIFIC RR	UNION PACIFIC RR
PORT-SEA MP 4.50	UNION PACIFIC RR	UNION PACIFIC RR

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE II

NAME	ENGINEER	CONTRACTOR
PORT-SPOK #7	UNION PACIFIC RR	UNION PACIFIC RR
PORT-SPOK #10	UNION PACIFIC RR	UNION PACIFIC RR
PORT-SPOK #11	UNION PACIFIC RR	UNION PACIFIC RR
2/108 TUNNEL #1	UNKNOWN	MYERS & GOULTER
14/216	UNKNOWN	MORRISON KNUDSEN
20/108	UNKNOWN	HWY CONST CO LTD
20/111	UNKNOWN	HWY CONST LTD
20/113N	UNKNOWN	UNKNOWN
97/24 MT BAKER	UNKNOWN	UNKNOWN
97/359 KNAPPS HILL	UNKNOWN	ELLIOTT & CO
101/23 FORT COL	WASH HWY DEPT	MORRISON-KNUDSEN
123/106	UNKNOWN	FED HWY ADMIN
12/308 RIMROCK	UNKNOWN	BJORK BROS
14/128 TUNNEL #1	UNKNOWN	MIRENE CO
14/129 TUNNEL #2	UNKNOWN	MIRENE CO
14/130 TUNNEL #3	UNKNOWN	MIRENE CO
14/133 TUNNEL #4	UNKNOWN	COLONIAL CONST CO
14/134 TUNNEL #5	UNKNOWN	COLONIAL CONST CO
14/215	UNKNOWN	MORRISON-KNUDSEN
YAKIMA MAIN CANAL	BU REC BOISE	UNKNOWN
KLAMATH CANAL A	BU REC BOISE	UNKNOWN
BLACK CANYON T#1	BU REC BOISE	UNKNOWN
BLACK CANYON T#2	BU REC BOISE	UNKNOWN
BLACK CANYON T#2A	BU REC BOISE	UNKNOWN
BLACK CANYON T#3	BU REC BOISE	UNKNOWN
BLACK CANYON T#4	BU REC BOISE	UNKNOWN
BLACK CANYON T#5	BU REC BOISE	UNKNOWN
BLACK CANYON T#6	BU REC BOISE	UNKNOWN
BLACK CANYON T#7	BU REC BOISE	UNKNOWN
BLACK CANYON T#8	BU REC BOISE	UNKNOWN
COLU BASIN BACON	BU REC BOISE	UNKNOWN
FRENCHMAN HILLS	BU REC BOISE	UNKNOWN
SNOW LAKE	BU REC BOISE	UNKNOWN
DESCHUTES T#1	BU REC BOISE	UNKNOWN
DESCHUTES T#2	BU REC BOISE	UNKNOWN
OWHYEE APPRH N CAN	BU REC BOISE	UNKNOWN
OWYHEE LATRL N CAN	BU REC BOISE	UNKNOWN
OWYHEE T#1 N CAN	BU REC BOISE	UNKNOWN
OWYHEE T#3 N CAN	BU REC BOISE	UNKNOWN
OWYHEE T#4 N CAN	BU REC BOISE	UNKNOWN
OWYHEE T#5 S CAN	BU REC BOISE	UNKNOWN
OWYHEE T#6 X CAN	BU REC BOISE	UNKNOWN

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE II

NAME	ENGINEER	CONTRACTOR
OWYHEE T#7 S CAN	BU REC BOISE	UNKNOWN
ROGUE RIV CAS DIV	BU REC BOISE	UNKNOWN
ROGUE RIV S FORK	BU REC BOISE	UNKNOWN
ROGUE RIV G S POWR	BU REC BOISE	UNKNOWN
VALE T#1	BU REC BOISE	UNKNOWN
VALE T#2	BU REC BOISE	UNKNOWN
VALE T#3	BU REC BOISE	UNKNOWN
VALE T#4	BU REC BOISE	UNKNOWN
VALE T#5	BU REC BOISE	UNKNOWN
YAKIMA KITTITAS MC	BU REC BOISE	UNKNOWN
T#2 S BRANCH CANAL	BU REC BOISE	UNKNOWN
ROZA DIV	BU REC BOISE	UNKNOWN
T#3 YAKIMA RIDGE	BU REC BOISE	UNKNOWN
T#5 YAKIMA RIDGE	BU REC BOISE	UNKNOWN
T#7 YAKIMA RIDGE	BU REC BOISE	UNKNOWN
T#8 YAKIMA RIDGE	BU REC BOISE	UNKNOWN
YAKIMA PROJECT	BU REC BOISE	UNKNOWN
YAKIMA ROCKY POINT	BU REC BOISE	UNKNOWN
YAKIMA RIVER	BU REC BOISE	UNKNOWN
T#1 N BRANCH CANAL	BU REC BOISE	UNKNOWN
T#2 N BRANCH CANAL	BU REC BOISE	UNKNOWN
T#3 N BRANCH CANAL	BU REC BOISE	UNKNOWN
T#4 N BRANCH CANAL	BU REC BOISE	UNKNOWN
T#5 N BRANCH CANAL	BU REC BOISE	UNKNOWN
T#1 S BRANCH CANAL	BU REC BOISE	UNKNOWN
PRINEVILLE U/S DIV	BU REC BOISE	SCHRADER CONSTR
PRINEVILLE D/S DIV	BU REC BOISE	SCHRADER CONSTR
KLAMATH CANAL A	BU REC BOISE	UNKNOWN
BLUE SLIDE	UNKNOWN	UNKNOWN
PALISADES	UNKNOWN	UNKNOWN
ROCKLAKE #43	UNKNOWN	UNKNOWN
WATTS #41	UNKNOWN	UNKNOWN
•2 MII E SPOKANE	UNKNOWN	UNKNOWN
EASTON	UNKNOWN	UNKNOWN
WHITTIER	UNKNOWN	UNKNOWN
JOHNSON CR #45	UNKNOWN	UNKNOWN
FASTON	UNKNOWN	UNKNOWN
HORLICK #2	UNKNOWN	UNKNOWN
HORLICK #2	UNKNOWN	UNKNOWN
TANCUM	UNKNOWN	UNKNOWN
SNDQUALMIE #50	UNKNOWN	UNKNOWN
VAIL	UNKNOWN	UNKNOWN

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE II

NAME	ENGINEER	CONTRACTOR
WOLF CREEK	UNKNOWN	UNKNOWN
CAPE HORN #1	UNKNOWN	UNKNOWN
CAPE HORN #10	UNKNOWN	UNKNOWN
CAPE HORN #11	UNKNOWN	UNKNOWN
CAPE HORN #12	UNKNOWN	UNKNOWN
CAPE HORN #13	UNKNOWN	UNKNOWN
CAPE HORN #15	UNKNOWN	UNKNOWN
CAPE HORN #16	UNKNOWN	UNKNOWN
CAPE HORN #17	UNKNOWN	UNKNOWN
CAPE HORN #18	UNKNOWN	UNKNOWN
FORT WRIGHT #19	UNKNOWN	UNKNOWN
O T RY #1	UNKNOWN	UNKNOWN
CAPE HORN #2	UNKNOWN	UNKNOWN
O T RY #2	UNKNOWN	UNKNOWN
O T RY #3	UNKNOWN	UNKNOWN
O T RY #4	UNKNOWN	UNKNOWN
GATEWAY #5	UNKNOWN	UNKNOWN
MAYGER #3	UNKNOWN	UNKNOWN
CORNELIUS	UNKNOWN	UNKNOWN
CAPE HORN #3	UNKNOWN	UNKNOWN
CASCADE	UNKNOWN	UNKNOWN
EVERETT #15	UNKNOWN	UNKNOWN
OROVILLE #7	UNKNOWN	UNKNOWN
SAMISH #18	UNKNOWN	UNKNOWN
SEATTLE #17	UNKNOWN	UNKNOWN
WINSTON #14	UNKNOWN	UNKNOWN
STAMPEDE #1	UNKNOWN	UNKNOWN
STAMPEDE #4	UNKNOWN	UNKNOWN
CAPE HORN #4	UNKNOWN	UNKNOWN
OSTRANDER	UNKNOWN	UNKNOWN
NELSON-BENNETT	UNKNOWN	UNKNOWN
RUSTON	UNKNOWN	UNKNOWN
CAPE HORN #5	UNKNOWN	UNKNOWN
CAPE HORN #6	UNKNOWN	UNKNOWN
CAPE HORN #7	UNKNOWN	UNKNOWN
CAPE HORN #8	UNKNOWN	UNKNOWN
CAPE HORN #9	UNKNOWN	UNKNOWN

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE III

NAME	DATE	USE	COST	KEY NO.
BLUE RIVER DAM DIV	40066	WATER	566340	12-1
COUGAR MAIN DIV	20057	WATER	306647	12-2-1
COUGAR PENSTOCK	20060	WATER	336240	12-2-2
COUGAR REG OUTLET	59	WATER	341640	12-2-3
COUGAR RUSH CREEK	20060	WATER	0	12-2-4
GREEN PETER DIV	30064	WATER	820200	12-3
BIG CLIFF DIV	50	WATER	270124	12-4
DETROIT DAM DIV	49	WATER	1132000	12-5
EAGLE GORGE OUTLET	0	WATER	0	13-1
HANSON DAM OUTLET	61	WATER	0	13-2
MUD MOUNTAIN 23D	48	WATER	0	13-3
MUD MOUNTAIN 9D	47	WATER	0	13-4
DWORSHAK DAM DIV	70066	WATER	0	14-1
LUCKY PEAK OUTLET	80050	WATER	0	14-2
CARMEN-SMITH POWER	0	WATER	0	17-1-1
CARMEN DIV	60062	WATER	0	17-1-2
KNOWLES CREEK	58	HIGHWAY	616641	26-1
SUNSET	41	HIGHWAY	141685	26-2
TOOTH ROCK	36	HIGHWAY	0	26-3
ELK CREEK	0	HIGHWAY	0	26-4
CAPE CREEK	0	HIGHWAY	0	26-5
ARCH CAPE	37	HIGHWAY	0	26-6
VISTA RIDGE WEST	69	HIGHWAY	4171982	26-7
VISTA RIDGE EAST	67	HIGHWAY	4562674	26-8
J C BOYLE PROJECT	58	WATER	714500	29-1
TOKETEE PROJECT	49	WATER	1484520	29-2
SWIFT TUNNEL	0	WATER	0	29-3
FARADAY DIV	31157	WATER	0	31-01-01
OAK GROVE	25	WATER	0	31-02-01
OAK GROVE #2	25	WATER	0	31-02-02
OAK GROVE #3	25	WATER	0	31-02-03
ROUND BUTTE POWER	41063	WATER	924217	31-03-01
ROUND BUTTE DIV	121961	WATER	1161960	31-03-02
ROUND BUTTE SPILL	21762	WATER	216514	31-03-03
ROUND BUTTE LL GRT	30962	OTHER	189628	31-03-04
ROUND BUTTE LL ACC	21262	OTHER	178208	31-03-05
ROUND BUTTE UL GRT	11262	OTHER	66620	31-03-06
ROUND BUTTE UL ACC	121961	OTHER	76428	31-03-07
ROUND BUTTE LR GRT	20162	OTHER	142757	31-03-08
ROUND BUTTE UR ACC	110361	OTHER	81054	31-03-10
ROUND BUTTE UR GRT	120161	OTHER	39734	31-03-11
BULL RUN #0	52726	WATER	29500	31-04-01

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE III

NAME	DATE	USE	COST	KEY NO.
BULL RUN #1	11	WATER	110000	31-04-02
BULL RUN #2	12	WATER	90000	31-04-03
BULL RUN #4	12	WATER	55000	31-04-04
ROUND BUTTE LR ACC	11262	OTHER	179873	32-03-09
BULL RUN DIV	61	WATER	1200000	32-1-1
BULL RUN LEFT ABT	61	WATER	916000	32-1-2
CAS#4 ABERNETHY	26	RAILROAD	0	36-1
CAS#16 FIELDS	26	RAILROAD	0	36-10
CAS#17 FIELDS	26	RAILROAD	0	36-11
CAS#11 FRAZIER	26	RAILROAD	0	36-12
CAS#12 FRAZIER	26	RAILROAD	0	36-13
CAS#13 FRAZIER	26	RAILROAD	0	36-14
CAS#14 FRAZIER	26	RAILROAD	0	36-15
CAS#23 LOOKOUT	26	RAILROAD	0	36-16
CAS#24 LOOKOUT	26	RAILROAD	0	36-17
CAS#21 MCCREDIE	26	RAILROAD	0	36-18
CAS#22 WESTFIR	26	RAILROAD	0	36-19
CAS#3 CASCADE SUMT	26	RAILROAD	0	36-2
CAS#18 WICOPEE	26	RAILROAD	0	36-20
CAS#19 WICOPEE	26	RAILROAD	0	36-21
CAS#20 WICOPEE	26	RAILROAD	0	36-22
COOS#16 CANARY	83	RAILROAD	0	36-23
COOS#15 CUSHMAN	83	RAILROAD	0	36-24
COOS#14 RICHARDSON	83	RAILROAD	0	36-25
COOS#17 KROLL	83	RAILROAD	0	36-26
COOS#18 KROLL	83	RAILROAD	0	36-27
COOS#19 REEDSPORT	83	RAILROAD	0	36-28
COOS#20 LAKESIDE	83	RAILROAD	0	36-29
CAS#5 CRUZATTE	26	RAILROAD	0	36-3
COOS#21 LAKESIDE	83	RAILROAD	0	36-30
COOS#13 VAUGHN	83	RAILROAD	0	36-31
SIS#1 CORNUTT	83	RAILROAD	0	36-32
SIS#2 GLENDALE	83	RAILROAD	0	36-33
SIS#3 GLENDALE	83	RAILROAD	0	36-34
SIS#4 GLENDALE	83	RAILROAD	0	36-35
SIS#5 GLENDALE	83	RAILROAD	0	36-36
SIS#6 GLENDALE	83	RAILROAD	0	36-37
SIS#7 GLENDALE	83	RAILROAD	0	36-38
SIS#9 HUGO	83	RAILROAD	0	36-39
CAS#6 CRUZATTE	26	RAILROAD	0	36-4
SIS#8 WOLFCREEK	83	RAILROAD	0	36-40
SIS#13 SISKIYOU	83	RAILROAD	0	36-41

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE III

NAME	DATE	USE	COST	KEY NO.
SIS#14 SISKIYOU	83	RAILROAD	0	36-42
SIS#15 SISKIYOU	83	RAILROAD	0	36-43
TIL#26 COCHRAN	12	RAILROAD	0	36-44
TIL#27 COCHRAN	12	RAILROAD	0	36-45
TIL#28 ENRIGHT	12	RAILROAD	0	36-46
TIL#29 ENRIGHT	12	RAILROAD	0	36-47
TIL#30 ENRIGHT	12	RAILROAD	0	36-48
TIL#32 ENRIGHT	12	RAILROAD	0	36-49
CAS#7 CRUZATTE	26	RAILROAD	0	36-5
TIL#34 ENRIGHT	12	RAILROAD	0	36-50
TIL#35 ENRIGHT	12	RAILROAD	0	36-51
TIL#36 ENRIGHT	12	RAILROAD	0	36-52
TIL#25 TIMBER	12	RAILROAD	0	36-53
TOL#24 EDDYVILLE	1	RAILROAD	0	36-54
JEF#38 WILSONIA	20	RAILROAD	0	36-55
CAS#8 CRUZATTE	26	RAILROAD	0	36-6
CAS#9 CRUZATTE	26	RAILROAD	0	36-7
CAS#10 CRUZATTE	26	RAILROAD	0	36-8
CAS#15 FIELDS	26	RAILROAD	0	36-9
MAYFIELD POWER	0	WATER	0	37-1
MAYFIELD DIV	55	WATER	2457342	37-2
MOSSY ROCK DIV #1	64	WATER	1520700	37-3-1
MAYFIELD DIV #2	0	WATER	831215	37-3-2
LA GRANDE POWER	0	WATER	1306836	37-4
CUSHMAN #2	29	WATER	0	37-5
CUSHMAN DIV	24	WATER	185853	37-6
PORT-HUNNING #1	9	RAILROAD	0	40-1
PORT-SPOK #12	12	RAILROAD	0	40-10
PORT-SPOK #13	12	RAILROAD	0	40-11
PORT-SPOK #14	12	RAILROAD	0	40-12
PORT-SPOK #15	12	RAILROAD	0	40-13
PORT-SPOK #16	12	RAILROAD	0	40-14
PORT-SPOK #17	12	RAILROAD	0	40-15
OLYMPIA BR MP 5.23	21	RAILROAD	0	40-16
OLYMPIA BR MP 5.76	46	RAILROAD	0	40-17
ORE EAST BR #16	37	RAILROAD	0	40-18
ORE EAST BR #17	37	RAILROAD	0	40-19
PORT-HUNNING #1.25	35	RAILROAD	0	40-2
PORT-HUNNING #1.50	22	RAILROAD	0	40-3
PORT-HUNNING #3.50	48	RAILROAD	0	40-4
PORT-HUNNING #6	28	RAILROAD	0	40-5
PORT-SEA MP 4.50	9	RAILROAD	0	40-6

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE III

NAME	DATE	USE	COST	KEY NO.
PORT-SPOK #7	99	RAILROAD	0	40-7
PORT-SPOK #10	12	RAILROAD	0	40-8
PORT-SPOK #11	12	RAILROAD	0	40-9
2/108 TUNNEL #1	110536	HIGHWAY	0	42-1
14/216	11833	HIGHWAY	0	42-10
20/108	52262	HIGHWAY	0	42-11
20/111	52262	HIGHWAY	0	42-12
20/113N	0	HIGHWAY	0	42-13
97/24 MT BAKER	39	HIGHWAY	0	42-14
97/359 KNAPPS HILL	31667	HIGHWAY	0	42-15
101/23 FORT COL	32	HIGHWAY	0	42-16
123/106	35	HIGHWAY	0	42-17
12/308 RIMROCK	21836	HIGHWAY	0	42-2
14/128 TUNNEL #1	91735	HIGHWAY	0	42-3
14/129 TUNNEL #2	91735	HIGHWAY	0	42-4
14/130 TUNNEL #3	91735	HIGHWAY	0	42-5
14/133 TUNNEL #4	91035	HIGHWAY	0	42-6
14/134 TUNNEL #5	91035	HIGHWAY	0	42-7
14/215	10833	HIGHWAY	0	42-8
YAKIMA MAIN CANAL	29	WATER	0	44-07-17
KLAMATH CANAL A	7	WATER	0	44-09-01
BLACK CANYON T#1	37	WATER	0	44-1-1
BLACK CANYON T#2	37	WATER	0	44-1-2
BLACK CANYON T#2A	38	WATER	0	44-1-3
BLACK CANYON T#3	37	WATER	0	44-1-4
BLACK CANYON T#4	37	WATER	0	44-1-5
BLACK CANYON T#5	37	WATER	0	44-1-6
BLACK CANY[illegible] T#6	37	WATER	0	44-1-7
BLACK CA[illegible] T#7	37	WATER	0	44-1-8
BLACK CAN[illegible]N T#8	32	WATER	0	44-1-9
COLU BASIN BACON	50	WATER	0	44-2-1
FRENCHMAN HILLS	53	WATER	0	44-2-2
SNOW LAKE	39	WATER	0	44-2-3
DESCHUTES T#1	45	WATER	0	44-3-1
DESCHUTES T#2	45	WATER	0	44-3-2
OWHYEE APPRH N CAN	35	WATER	0	44-4-1
OWYHEE LATRL N CAN	32	WATER	0	44-4-2
OWYHEE T#1 N CAN	32	WATER	0	44-4-3
OWYHEE T#3 N CAN	34	WATER	0	44-4-4
OWYHEE T#4 N CAN	34	WATER	0	44-4-5
OWYHEE T#5 S CAN	33	WATER	0	44-4-6
OWYHEE T#6 X CAN	35	WATER	0	44-4-7

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE III

NAME	DATE	USE	COST	KEY NO.
OWYHEE T#7 S CAN	35	WATER	0	44-4-8
ROGUE RIV CAS DIV	59	WATER	0	44-5-1
ROGUE RIV S FORK	58	WATER	0	44-5-2
ROGUE RIV G S POWR	59	WATER	0	44-5-3
VALE T#1	29	WATER	0	44-6-1
VALE T#2	30	WATER	0	44-6-2
VALE T#3	29	WATER	0	44-6-3
VALE T#4	30	WATER	0	44-6-4
VALE T#5	30	WATER	0	44-6-5
YAKIMA KITTITAS MC	29	WATER	0	44-7-1
T#2 S BRANCH CANAL	29	WATER	0	44-7-10
ROZA DIV	38	WATER	0	44-7-11
T#3 YAKIMA RIDGE	38	WATER	0	44-7-12
T#5 YAKIMA RIDGE	39	WATER	0	44-7-13
T#7 YAKIMA RIDGE	39	WATER	0	44-7-14
T#8 YAKIMA RIDGE	39	WATER	0	44-7-15
YAKIMA PROJECT	39	WATER	0	44-7-16
YAKIMA ROCKY POINT	29	WATER	0	44-7-2
YAKIMA RIVER	31	WATER	0	44-7-3
T#1 N BRANCH CANAL	28	WATER	0	44-7-4
T#2 N BRANCH CANAL	29	WATER	0	44-7-5
T#3 N BRANCH CANAL	29	WATER	0	44-7-6
T#4 N BRANCH CANAL	30	WATER	0	44-7-7
T#5 N BRANCH CANAL	31	WATER	0	44-7-8
T#1 S BRANCH CANAL	28	WATER	0	44-7-9
PRINEVILLE U/S DIV	102659	WATER	123569	44-8-1
PRINEVILLE D/S DIV	102659	WATER	77324	44-8-2
KLAMATH CANAL A	7	WATER	0	44-9-1
BLUE SLIDE	10	RAILROAD	113129	45-1
PALISADES	8	RAILROAD	55210	45-10
ROCKLAKE #43	8	RAILROAD	52626	45-11
WATTS #41	8	RAILROAD	391649	45-12
.2 MII E SPOKANE	0	RAILROAD	0	45-13
EASTON	0	RAILROAD	0	45-14
WHITTIER	0	RAILROAD	0	45-15
JOHNSON CR #45	8	RAILROAD	205859	45-2
FASTON	8	RAILROAD	26151	45-3
HORLICK #2	0	RAILROAD	0	45-4
HORLICK #2	8	RAILROAD	160432	45-5
TANCUM	8	RAILROAD	70722	45-6
SNDQUALMIE #50	8	RAILROAD	2504968	45-7
VAIL	10	RAILROAD	67155	45-8

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE III

NAME	DATE	USE	COST	KEY NO.
WOLF CREEK	10	RAILROAD	5946	45-9
CAPE HORN #1	6	RAILROAD	142814	5-1
CAPE HORN #10	6	RAILROAD	78342	5-10
CAPE HORN #11	6	RAILROAD	12892	5-11
CAPE HORN #12	6	RAILROAD	75007	5-12
CAPE HORN #13	8	RAILROAD	12983	5-13
CAPE HORN #15	8	RAILROAD	35882	5-14
CAPE HORN #16	8	RAILROAD	257897	5-15
CAPE HORN #17	8	RAILROAD	333152	5-16
CAPE HORN #18	8	RAILROAD	44737	5-17
FORT WRIGHT #19	10	RAILROAD	303245	5-18
O T RY #1	10	RAILROAD	245797	5-19
CAPE HORN #2	6	RAILROAD	6452	5-2
O T RY #2	10	RAILROAD	84758	5-20
O T RY #3	10	RAILROAD	127588	5-21
O T RY #4	10	RAILROAD	155447	5-22
GATEWAY #5	11	RAILROAD	0	5-23
MAYGER #3	98	RAILROAD	9576	5-24
CORNELIUS	11	RAILROAD	790801	5-25
CAPE HORN #3	6	RAILROAD	53915	5-3
CASCADE	28	RAILROAD	*******	5-32
EVERETT #15	0	RAILROAD	369410	5-33
OROVILLE #7	6	RAILROAD	121987	5-34
SAMISH #18	2	RAILROAD	114276	5-35
SEATTLE #17	6	RAILROAD	1042536	5-36
WINSTON #14	28	RAILROAD	818061	5-37
STAMPEDE #1	86	RAILROAD	1922024	5-38
STAMPEDE #4	87	RAILROAD	98552	5-39
CAPE HORN #4	6	RAILROAD	36786	5-4
OSTRANDER	10	RAILROAD	192359	5-40
NELSON-BENNETT	13	RAILROAD	849354	5-41
RUSTON	14	RAILROAD	167770	5-42
CAPE HORN #5	6	RAILROAD	59254	5-5
CAPE HORN #6	6	RAILROAD	78833	5-6
CAPE HORN #7	6	RAILROAD	154957	5-7
CAPE HORN #8	6	RAILROAD	113043	5-8
CAPE HORN #9	6	RAILROAD	52209	5-9

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE IV

NAME	SHAPE	LENGTH	SPAN	USE
BLUE RIVER DAM DIV	CIRCULAR	1795	25	WATER
COUGAR MAIN DIV	ARCHED ROOF	1834	20	WATER
COUGAR PENSTOCK	ARCHED ROOF	1043	15	WATER
COUGAR REG OUTLET	CIRCULAR	963	23	WATER
COUGAR RUSH CREEK	ARCHED ROOF	630	8	WATER
GREEN PETER DIV	ARCHED ROOF	1050	29	WATER
BIG CLIFF DIV	ARCHED ROOF	631	22	WATER
DETROIT DAM DIV	HORSESHOE	1364	34	WATER
EAGLE GORGE OUTLET	ARCHED ROOF	0	23	WATER
HANSON DAM OUTLET	ARCHED ROOF	886	23	WATER
MUD MOUNTAIN 23D	CIRCULAR	1991	27	WATER
MUD MOUNTAIN 9D	ARCHED ROOF	1800	11	WATER
DWORSHAK DAM DIV	HORSESHOE	1722	53	WATER
LUCKY PEAK OUTLET	CIRCULAR	1161	23	WATER
CARMEN-SMITH POWER	HORSESHOE	7284	14	WATER
CARMEN DIV	ARCHED ROOF	11381	11	WATER
KNOWLES CREEK	ARCHED ROOF	1430	36	HIGHWAY
SUNSET	ARCHED ROOF	800	39	HIGHWAY
TOOTH ROCK	ARCHED ROOF	837	40	HIGHWAY
ELK CREEK	ARCHED ROOF	1090	30	HIGHWAY
CAPE CREEK	ARCHED ROOF	714	34	HIGHWAY
ARCH CAPE	ARCHED ROOF	1228	36	HIGHWAY
VISTA RIDGE WEST	ARCHED ROOF	1001	58	HIGHWAY
VISTA RIDGE EAST	ARCHED ROOF	1049	58	HIGHWAY
J C BOYLE PROJECT	HORSESHOE	1662	16	WATER
TOKETEE PROJECT	UNKNOWN	5400	17	WATER
SWIFT TUNNEL	UNKNOWN	0	0	WATER
FARADAY DIV	HORSESHOE	2426	23	WATER
OAK GROVE	CIRCULAR	170	14	WATER
OAK GROVE #2	CIRCULAR	250	14	WATER
OAK GROVE #3	CIRCULAR	1300	12	WATER
ROUND BUTTE POWER	CIRCULAR	1520	23	WATER
ROUND BUTTE DIV	CIRCULAR	2093	21	WATER
ROUND BUTTE SPILL	CIRCULAR	390	21	WATER
ROUND BUTTE LL GRT	RECTANGULAR	797	9	OTHER
ROUND BUTTE LL ACC	RECTANGULAR	963	7	OTHER
ROUND BUTTE UL GRT	RECTANGULAR	280	9	OTHER
ROUND BUTTE UL ACC	RECTANGULAR	413	7	OTHER
ROUND BUTTE LR GRT	RECTANGULAR	600	9	OTHER
ROUND BUTTE UR ACC	RECTANGULAR	438	7	OTHER
ROUND BUTTE UR GRT	RECTANGULAR	167	9	OTHER
BULL RUN #0	HORSESHOE	457	11	WATER

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE IV

NAME	SHAPE	LENGTH	SPAN	USE
BULL RUN #1	HORSESHOE	4702	9	WATER
BULL RUN #2	HORSESHOE	1550	13	WATER
BULL RUN #4	HORSESHOE	2180	13	WATER
ROUND BUTTE LR ACC	RECTANGULAR	972	7	OTHER
BULL RUN DIV	CIRCULAR	1000	15	WATER
BULL RUN LEFT ABT	CIRCULAR	1700	7	WATER
CAS#4 ABERNETHY	ARCHED ROOF	698	22	RAILROAD
CAS #16 FIELDS	ARCHED ROOF	2213	22	RAILROAD
CAS #17 FIELDS	ARCHED ROOF	267	22	RAILROAD
CAS #11 FRAZIER	ARCHED ROOF	779	22	RAILROAD
CAS #12 FRAZIER	ARCHED ROOF	360	21	RAILROAD
CAS #13 FRAZIER	ARCHED ROOF	875	22	RAILROAD
CAS #14 FRAZIER	ARCHED ROOF	2121	21	RAILROAD
CAS #23 LOOKOUT	ARCHED ROOF	654	22	RAILROAD
CAS #24 LOOKOUT	ARCHED ROOF	394	22	RAILROAD
CAS #21 MCCREDIE	ARCHED ROOF	561	22	RAILROAD
CAS #22 WESTFIR	ARCHED ROOF	1999	21	RAILROAD
CAS#3 CASCADE SUMT	ARCHED ROOF	3655	21	RAILROAD
CAS #18 WICOPEE	ARCHED ROOF	640	22	RAILROAD
CAS #19 WICOPEE	ARCHED ROOF	363	22	RAILROAD
CAS #20 WICOPEE	ARCHED ROOF	436	22	RAILROAD
COOS #16 CANARY	ARCHED ROOF	624	22	RAILROAD
COOS #15 CUSHMAN	ARCHED ROOF	2143	21	RAILROAD
COOS #14 RICHARDSON	ARCHED ROOF	473	22	RAILROAD
COOS #17 KROLL	ARCHED ROOF	1200	21	RAILROAD
COOS #18 KROLL	ARCHED ROOF	1556	21	RAILROAD
COOS #19 REEDSPORT	ARCHED ROOF	4183	21	RAILROAD
COOS #20 LAKESIDE	ARCHED ROOF	870	22	RAILROAD
CAS #5 CRUZATTE	ARCHED ROOF	964	22	RAILROAD
COOS #21 LAKESIDE	ARCHED ROOF	475	22	RAILROAD
COOS #13 VAUGHN	ARCHED ROOF	2489	21	RAILROAD
SIS #1 CORNUTT	ARCHED ROOF	264	22	RAILROAD
SIS #2 GLENDALE	ARCHED ROOF	423	22	RAILROAD
SIS #3 GLENDALE	ARCHED ROOF	433	22	RAILROAD
SIS #4 GLENDALE	ARCHED ROOF	332	22	RAILROAD
SIS #5 GLENDALE	ARCHED ROOF	341	22	RAILROAD
SIS #6 GLENDALE	ARCHED ROOF	517	22	RAILROAD
SIS #7 GLENDALE	ARCHED ROOF	128	22	RAILROAD
SIS #9 HUGO	ARCHED ROOF	2105	21	RAILROAD
CAS #6 CRUZATTE	ARCHED ROOF	566	21	RAILROAD
SIS #8 WOLFCREEK	ARCHED ROOF	2812	21	RAILROAD
SIS #13 SISKIYOU	ARCHED ROOF	3108	21	RAILROAD

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE IV

NAME	SHAPE	LENGTH	SPAN	USE
SIS#14 SISKIYOU	ARCHED ROOF	1192	22	RAILROAD
SIS#15 SISKIYOU	ARCHED ROOF	258	22	RAILROAD
TIL#26 COCHRAN	ARCHED ROOF	414	22	RAILROAD
TIL#27 COCHRAN	ARCHED ROOF	412	22	RAILROAD
TIL#28 ENRIGHT	ARCHED ROOF	240	21	RAILROAD
TIL#29 ENRIGHT	ARCHED ROOF	292	22	RAILROAD
TIL#30 ENRIGHT	ARCHED ROOF	262	21	RAILROAD
TIL#32 ENRIGHT	ARCHED ROOF	500	22	RAILROAD
CAS#7 CRUZATTE	ARCHED ROOF	3164	22	RAILROAD
TIL#34 ENRIGHT	ARCHED ROOF	303	22	RAILROAD
TIL#35 ENRIGHT	ARCHED ROOF	251	22	RAILROAD
TIL#36 ENRIGHT	ARCHED ROOF	179	22	RAILROAD
TIL#25 TIMBER	ARCHED ROOF	1417	21	RAILROAD
TOL#24 EDDYVILLE	ARCHED ROOF	682	21	RAILROAD
JEF#38 WILSONIA	ARCHED ROOF	1396	22	RAILROAD
CAS#8 CRUZATTE	ARCHED ROOF	371	22	RAILROAD
CAS#9 CRUZATTE	ARCHED ROOF	1144	21	RAILROAD
CAS#10 CRUZATTE	ARCHED ROOF	467	22	RAILROAD
CAS#15 FIELDS	ARCHED ROOF	150	21	RAILROAD
MAYFIELD POWER	HORSESHOE	830	45	WATER
MAYFIELD DIV	HORSESHOE	548	**	WATER
MOSSY ROCK DIV #1	ARCHED ROOF	1794	33	WATER
MAYFIELD DIV #2	ARCHED ROOF	1488	33	WATER
LA GRANDE POWER	UNKNOWN	6236	14	WATER
CUSHMAN #2	UNKNOWN	0	17	WATER
CUSHMAN DIV	UNKNOWN	0	0	WATER
PORT-HUNNING #1	ARCHED ROOF	654	32	RAILROAD
PORT-SPOK #12	ARCHED ROOF	494	21	RAILROAD
PORT-SPOK #13	ARCHED ROOF	958	21	RAILROAD
PORT-SPOK #14	ARCHED ROOF	593	21	RAILROAD
PORT-SPOK #15	ARCHED ROOF	909	21	RAILROAD
PORT-SPOK #16	ARCHED ROOF	667	22	RAILROAD
PORT-SPOK #17	ARCHED ROOF	426	21	RAILROAD
OLYMPIA BR MP 5.23	ARCHED ROOF	108	22	RAILROAD
OLYMPIA BR MP 5.76	ARCHED ROOF	565	22	RAILROAD
ORE EAST BR #16	ARCHED ROOF	2537	22	RAILROAD
ORE EAST BR #17	ARCHED ROOF	138	22	RAILROAD
PORT-HUNNING #1.25	ARCHED ROOF	635	34	RAILROAD
PORT-HUNNING #1.50	ARCHED ROOF	418	34	RAILROAD
PORT-HUNNING #3.50	ARCHED ROOF	610	22	RAILROAD
PORT-HUNNING #6	ARCHED ROOF	518	22	RAILROAD
PORT-SEA MP 4.50	ARCHED ROOF	5436	22	RAILROAD

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE IV

NAME	SHAPE	LENGTH	SPAN	USE
PORT-SPOK #7	ARCHED ROOF	623	22	RAILROAD
PORT-SPOK #10	ARCHED ROOF	994	21	RAILROAD
PORT-SPOK #11	ARCHED ROOF	1760	21	RAILROAD
2/108 TUNNEL #1	UNKNOWN	184	20	HIGHWAY
14/216	UNKNOWN	233	15	HIGHWAY
20/108	UNKNOWN	603	21	HIGHWAY
20/111	UNKNOWN	88	21	HIGHWAY
20/113N	UNKNOWN	361	16	HIGHWAY
97/24 MT BAKER	UNKNOWN	1466	19	HIGHWAY
97/359 KNAPPS HILL	UNKNOWN	740	16	HIGHWAY
101/23 FORT COL	UNKNOWN	800	18	HIGHWAY
123/106	UNKNOWN	510	19	HIGHWAY
12/308 RIMROCK	UNKNOWN	577	17	HIGHWAY
14/128 TUNNEL #1	UNKNOWN	130	18	HIGHWAY
14/129 TUNNEL #2	UNKNOWN	408	18	HIGHWAY
14/130 TUNNEL #3	UNKNOWN	257	18	HIGHWAY
14/133 TUNNEL #4	UNKNOWN	261	19	HIGHWAY
14/134 TUNNEL #5	UNKNOWN	212	19	HIGHWAY
14/215	UNKNOWN	389	15	HIGHWAY
YAKIMA MAIN CANAL	HORSESHOE	305	12	WATER
KLAMATH CANAL A	UNKNOWN	3300	14	WATER
BLACK CANYON T#1	HORSESHOE	825	14	WATER
BLACK CANYON T#2	HORSESHOE	475	14	WATER
BLACK CANYON T#2A	HORSESHOE	422	14	WATER
BLACK CANYON T#3	HORSESHOE	1375	14	WATER
BLACK CANYON T#4	HORSESHOE	1270	14	WATER
BLACK CANYON T#5	HORSESHOE	640	14	WATER
BLACK CANYON T#6	HORSESHOE	870	14	WATER
BLACK CANYON T#7	HORSESHOE	1630	14	WATER
BLACK CANYON T#8	HORSESHOE	3170	9	WATER
COLU BASIN BACON	HORSESHOE	10037	23	WATER
FRENCHMAN HILLS	HORSESHOE	9280	14	WATER
SNOW LAKE	UNKNOWN	2560	6	WATER
DESCHUTES T#1	HORSESHOE	3443	11	WATER
DESCHUTES T#2	HORSESHOE	3361	11	WATER
OWHYEE APPRH N CAN	HORSESHOE	440	12	WATER
OWYHEE LATRL N CAN	HORSESHOE	350	5	WATER
OWYHEE T#1 N CAN	HORSESHOE	18723	17	WATER
OWYHEE T#3 N CAN	HORSESHOE	1354	14	WATER
OWYHEE T#4 N CAN	HORSESHOE	1990	12	WATER
OWYHEE T#5 S CAN	HORSESHOE	21948	9	WATER
OWYHEE T#6 X CAN	HORSESHOE	1040	8	WATER

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
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NAME	SHAPE	LENGTH	SPAN	USE
OWYHEE T#7 S CAN	HORSESHOE	4325	7	WATER
ROGUE RIV CAS DIV	CIRCULAR	2100	6	WATER
ROGUE RIV S FORK	HORSESHOE	3553	6	WATER
ROGUE RIV G S POWR	CIRCULAR	4833	6	WATER
VALE T#1	HORSESHOE	2150	11	WATER
VALE T#2	HORSESHOE	5007	11	WATER
VALE T#3	HORSESHOE	1312	11	WATER
VALE T#4	HORSESHOE	500	10	WATER
VALE T#5	HORSESHOE	286	10	WATER
YAKIMA KITTITAS MC	HORSESHOE	179	12	WATER
T#2 S BRANCH CANAL	HORSESHOE	1390	5	WATER
ROZA DIV	HORSESHOE	8231	17	WATER
T#3 YAKIMA RIDGE	HORSESHOE	9358	17	WATER
T#5 YAKIMA RIDGE	HORSESHOE	3988	14	WATER
T#7 YAKIMA RIDGE	HORSESHOE	755	13	WATER
T#8 YAKIMA RIDGE	HORSESHOE	1475	13	WATER
YAKIMA PROJECT	HORSESHOE	1475	13	WATER
YAKIMA ROCKY POINT	HORSESHOE	305	12	WATER
YAKIMA RIVER	CIRCULAR	3640	9	WATER
T#1 N BRANCH CANAL	HORSESHOE	1686	12	WATER
T#2 N BRANCH CANAL	HORSESHOE	1025	12	WATER
T#3 N BRANCH CANAL	HORSESHOE	2276	12	WATER
T#4 N BRANCH CANAL	HORSESHOE	482	11	WATER
T#5 N BRANCH CANAL	HORSESHOE	3470	7	WATER
T#1 S BRANCH CANAL	HORSESHOE	2000	6	WATER
PRINEVILLE U/S DIV	CIRCULAR	529	11	WATER
PRINEVILLE D/S DIV	ARCHED ROOF	331	11	WATER
KLAMATH CANAL A	UNKNOWN	3300	14	WATER
BLUE SLIDE	UNKNOWN	1093	15	RAILROAD
PALISADES	UNKNOWN	704	15	RAILROAD
ROCKLAKE #43	UNKNOWN	756	18	RAILROAD
WATTS #41	UNKNOWN	2559	16	RAILROAD
.2 MI E SPOKANE	UNKNOWN	863	0	RAILROAD
EASTON	UNKNOWN	203	0	RAILROAD
WHITTIER	UNKNOWN	528	0	RAILROAD
JOHNSON CR #45	UNKNOWN	1973	15	RAILROAD
FASTON	UNKNOWN	203	15	RAILROAD
HORLICK #2	UNKNOWN	496	0	RAILROAD
HORLICK #2	UNKNOWN	1239	17	RAILROAD
TANCUM	UNKNOWN	496	16	RAILROAD
SNOQUALMIE #50	UNKNOWN	11890	15	RAILROAD
VAIL	UNKNOWN	810	15	RAILROAD

GENERAL DATA FILE FOR
TUNNELS IN THE OREGON AND WASHINGTON AREA
TABLE IV

NAME	SHAPE	LENGTH	SPAN	USE
WOLF CREEK	UNKNOWN	90	17	RAILROAD
CAPE HORN #1	ARCHED ROOF	2369	16	RAILROAD
CAPE HORN #10	ARCHED ROOF	576	16	RAILROAD
CAPE HORN #11	ARCHED ROOF	269	16	RAILROAD
CAPE HORN #12	ARCHED ROOF	385	16	RAILROAD
CAPE HORN #13	ARCHED ROOF	203	16	RAILROAD
CAPE HORN #15	ARCHED ROOF	323	16	RAILROAD
CAPE HORN #16	ARCHED ROOF	2494	16	RAILROAD
CAPE HORN #17	ARCHED ROOF	2220	16	RAILROAD
CAPE HORN #18	ARCHED ROOF	369	16	RAILROAD
FORT WRIGHT #19	ARCHED ROOF	2134	16	RAILROAD
O T RY #1	ARCHED ROOF	814	16	RAILROAD
CAPE HORN #2	ARCHED ROOF	122	16	RAILROAD
O T RY #2	ARCHED ROOF	810	16	RAILROAD
O T RY #3	ARCHED ROOF	480	16	RAILROAD
O T RY #4	ARCHED ROOF	384	16	RAILROAD
GATEWAY #5	ARCHED ROOF	242	16	RAILROAD
MAYGER #3	ARCHED ROOF	175	16	RAILROAD
CORNELIUS	ARCHED ROOF	4111	16	RAILROAD
CAPE HORN #3	ARCHED ROOF	416	16	RAILROAD
CASCADE	UNKNOWN	41152	16	RAILROAD
EVERETT #15	UNKNOWN	2440	16	RAILROAD
OROVILLE #7	UNKNOWN	1761	18	RAILROAD
SAMISH #18	UNKNOWN	1113	16	RAILROAD
SEATTLE #17	UNKNOWN	5142	30	RAILROAD
WINSTON #14	UNKNOWN	4059	16	RAILROAD
STAMPEDE #1	UNKNOWN	9834	16	RAILROAD
STAMPEDE #4	UNKNOWN	649	16	RAILROAD
CAPE HORN #4	ARCHED ROOF	267	16	RAILROAD
OSTRANDER	UNKNOWN	1165	28	RAILROAD
NELSON-BENNETT	UNKNOWN	4391	28	RAILROAD
RUSTON	UNKNOWN	323	28	RAILROAD
CAPE HORN #5	ARCHED ROOF	395	16	RAILROAD
CAPE HORN #6	ARCHED ROOF	657	16	RAILROAD
CAPE HORN #7	ARCHED ROOF	966	16	RAILROAD
CAPE HORN #8	ARCHED ROOF	755	16	RAILROAD
CAPE HORN #9	ARCHED ROOF	392	16	RAILROAD

General Data Form

Key Number______________________________________

Project Name______________________________________

Owner______________________________________

Engineer______________________________________

Contractor______________________________________

Date Finished____________________

Shape:

- ☐ Circular
- ☐ Horseshoe
- ☐ Rectangular
- ☐ Square
- ☐ Trapezoidal
- ☐ Arched Roof
- ☐ Oval

Length____________________

Diameter or Span____________________

Cost____________________

Use:

- ☐ Railroad
- ☐ Highway
- ☐ Water
- ☐ Other

Location______________________________________

(County) (State)

Exploration Data Form

Field #1 Key Number____________________

Field #2 Type of Reconnaissance

☐ Aerial ☐ Field

☐ Map

Field #3 Reconniassance Performed by

☐ Geologist ☐ In House

☐ Engineer ☐ Consultant

Field #4 Years Experience__________

DRILLING PROGRAM

Field #5 Number of Holes____________________

Field #6 Type of Drill

☐ Auger ☐ Wash Boring

☐ Diamond Rotary Drill ☐ Churn Drill

Core Drill ☐ Jetting

Field #7 Diameter of Holes____________________ inches

Field #8 Penetration Tests____________________

Field #9 Water Pressure Tests____________________

Field #10 Drill Log Available ☐ Yes ☐ No

Field #11 RQD ☐ Yes ☐ No

Field #12 Location of Holes ☐ Portal Areas Only

☐ Throughout Tunnel Length

☐ Random Spacing

Field #13 Regular Spacing

Intervals of holes ______________ feet

Field #14 Located by Geologist

Field #15 Cost ______________ dollars

PILOT BORE

Field #16 Contractor ______________

Field #17 Length ______________ linear feet

Field #18 Shape

- ☐ Round
- ☐ Oval
- ☐ Rectangular
- ☐ Horseshoe

Field #19 Diameter of Span ______________ feet

Field #20 Location of Pilot Bore with Respect to Main Bore

- ☐ Off Alignment
- ☐ Bottom of Heading
- ☐ Top of Heading
- ☐ Edge of Heading
- ☐ Center of Heading

Field #21 Use of Pilot Bore During Construction

- ☐ None
- ☐ Blasting Improvement
- ☐ Ventilation
- ☐ Access
- ☐ Muck Hauling

Field #22 Geologic Map Available ☐ Yes ☐ No

Field #23 Cost of Pilot Tunnel ______________ dollars

LAB TESTING

Soil Tests

Field #24 Specific Gravity ______________________

Field #25 Atterberg Limits ______________________

Shear Tests

Field #26 Direct ______________________

Field #27 Triaxial ______________________

Field #28 Consolidated ______________________

Field #29 Unconfined ______________________

Field #30 Drained ______________________

Field #31 Consolidation ______________________

Field #32 Other ______________________

Rock Tests

Modulus of Elasticity

Field #33 Static ______________________

Field #34 Dynamic ______________________

Strength Tests

Field #35 Unconfined ______________________

Field #36 Triaxial ______________________

Field #37 Tensile ______________________

Field #38 Direct Shear ______________________

Water Tests

Field #39 Sulfide Reactive ______________________

Field #40 Other ______________________

Field #41 Cost of Lab Testing ______________________ dollars

FIELD TESTS

Field #42 Prop Load Cells ______________________ number

Field #43 Rock Bolt Load Cells ______________________ number

Field #44 Extensometer:

☐ Single Position ☐ 8 Position

☐ Multiple other than 8, what ______________

Field #45 Readout:

☐ Electric ☐ Mechanical

☐ Rod ☐ Wire

Field #46 Anchorage:

☐ Expandable Packer ☐ Grout Anchor

☐ Mechanical Anchor

Field #47 Length ______________________ feet

Field #48 Number ______________________

Rock Bolt Tests

Field #49 Pull Tests ______________________

Field #50 Load Retention ______________________

Field #51 Diameter of Bolt ______________________ inches

Field #52 Type of Anchor:

☐ Slot and Wedge ☐ Cone and Wedge

☐ Fingered and Wedge ☐ Grout

☐ Bail and Wedge ☐ Other

Field #53	Type of Bolt:		
	☐ Hollow	☐ Solid	
Field #54	Plate Loading Test ______________		
Field #55	Type		
	☐ Horizontal	☐ Vertical	
	☐ Rock	☐ Soil	
Field #56	Area of Plate ______________		square inches
Field #57	Maximum Load ______________		pounds
Field #58	Flat Jack Tests ______________		
Field #59	Type		
	☐ Horizontal	☐ Vertical	
	☐ Other		
Field #60	Jack Size ______________		square inches
Field #61	Overcoring		
Field #62	Exterior Hole Diameter ______________		inches
Field #63	Interior Hole Diameter ______________		inches
Field #64	Number of Axes on Gauge ______________		
Field #65	Pressure Chamber Tests ______________		
Field #66	In Situ Shear Tests ______________		
Field #67	Surface Subsidence Measurements ______________		
Field #68	Tunnel Shape Change Monitoring ______________		
Field #69	Cost of ______________		dollars

SIESMIC SURVEY

Field #70 Number of Lines______________________

Field #71 Total Length of Lines__________________ linear feet

Field #72 Cost of Survey________________________ dollars

Construction Data Form

Field #1 Key Number ______________________

Field #2 Type of Contract

- ☐ Prime
- ☐ Sub

EXCAVATION

Field #3 Soft Ground

- ☐ Full Face
- ☐ Fore Poling
- ☐ Shield
- ☐ Breast Boards
- ☐ Compressed Air
- ☐ Multiple Drifts

Field #4 Multiple Drift Types:

- ☐ American
- ☐ Italian
- ☐ English
- ☐ Australian
- ☐ Belgian
- ☐ German

Field #5 Rock

- ☐ Full Face
- ☐ Top Heading and Bench
- ☐ Bottom Heading

Field #6 Type of Round:

- ☐ Vee Cut
- ☐ Draw Cut
- ☐ Burn Hole
- ☐ Pyramid Cut
- ☐ Double V or Wedge

Field #7 Length of Round ______________________ feet

Field #8 Number of Holes per Round ______________

Field #9 Number of Drills Used ____________________

Field #10 Average Bit Lift ____________________ hours

Field #11 Average Drill Time ____________________ minutes

Field #12 Minimum Drill Time ____________________ minutes

Field #13 Type of Explosives:

☐ Black Powder

Field #14 Grade of Black Powder:

☐ Grade A ☐ Grade B

☐ Granulation ☐ Pellet Powder

☐ Dynamite

Description of Dynamite:

Field #15 % of Nitro ____________________

Field #16 Density ____________________

Field #17 Diameter of Cartridge __________ inches

Field #18 Length of Cartridge __________ inches

Field #19 Type of Dynamite:

☐ Straight ☐ Special Gelatin

☐ Red Cross Extra ☐ Gelex

☐ Red Cross ☐ Duobel

☐ Extra ☐ Monobel

☐ Hi Cap ☐ Lump Coal

☐ Gelatin ☐ Gelobel

☐ Hi Velocity Gelatin

Type of Explosives (cont):

- [ ] Nitramon
- [ ] Nitramex
- [ ] Free Running

Field #20 Type of Ignition System:

- [ ] Ignitacord
- [ ] Squibs
- [ ] Safety Fuse
- [ ] Caps
- [ ] Primacord

Field #21 Powder Factor ______________________

Field #22 Stemming:

Field #23 Average Load Time ______________ minutes

Field #24 Minimum Load Time ______________ minutes

Field #25 Type of Boring Machine:

- [ ] Roller Cutter
- [ ] Disc Cutter
- [ ] Solid Cutter

MUCKING

Field #26 Type of Mucking:

- [ ] Hand
- [ ] Mechanical

Field #27 Type of Mechanical Mucking:

- [ ] Rubber Tired
- [ ] Diesel Operated
- [ ] Track Mounted
- [ ] Electrically Operated

Field #28 Air Operated

Field #29 Bucket Size____________________ yard

Field #30 Hp Power____________________ hp

Field #31 Car Capacity____________________ yard

Field #32 Type of Haulage:

- ☐ Electric
- ☐ Animal
- ☐ Diesel
- ☐ Air

Field #33 Average Mucking Time____________________ minutes

Field #34 Minimum Mucking Time____________________ minutes

VENTILATION

Field #35 Type of Ventilation

- ☐ Blower
- ☐ Open Compressed Air Line
- ☐ Exhaust
- ☐ None
- ☐ Both

Field #36 Diameter of Fan Line____________________ inches

Field #37 Average Ventilation Time____________________ minutes

Field #38 Minimum Ventilation Time____________________ minutes

RATE OF ADVANCE

Field #39 Number of Headings____________________

Field #40 Average Daily____________________ feet

Field #41 Best Daily____________________ feet

Field #42 Worst Daily ______________________ feet

Field #43 Best Weekly ______________________ feet

Field #44 Best Monthly ______________________ feet

UNUSUAL CONDITIONS

Excessive Water:

Field #45 Maximum Inflow of Water ______________________ cfm

Field #46 Average Inflow of Water ______________________ cfm

Field #47 Maximum Press ______________________ psi

Field #48 Average Press ______________________ psi

Field #49 Ground Temperature ______________________ °F

Field #50 Gas:

- [ ] Poisonous
- [ ] Explosive
- [ ] Both

TEMPORARY SUPPORTS

Field #51 Type of Temporary Supports:

Timber:

Field #52 Length Supported ______________________ linear feet

Field #53 Types of Timber Sets:

- [ ] Post and Cap
- [ ] 4 Piece
- [ ] Arch Set
- [ ] Cap and Hitches

Field #54 Average Spacing ______________________ feet

Field #55 Minimum Spacing____________________ feet

Field #56 Size____________________

Field #57 Number of Pieces____________________

Steel:

Field #58 Type of Steel Sets

- ☐ Wall Plates
- ☐ Struts
- ☐ Full Circle Rib

Rock Bolts:

Field #59 Type of Rock Bolts

- ☐ Pattern Bolts
- ☐ Random
- ☐ Both

Field #60 Length Bolted____________________ linear feet

Field #61 Spacing____________________ feet

Field #62 Bolt Length____________________ feet

Field #63 Type of Anchor

- ☐ Slot and Wedge
- ☐ Cone and Wedge
- ☐ Wedge and Bail
- ☐ Grout
- ☐ Finger and Wedge

Field #64 Surface Preparation:

- ☐ Pads
- ☐ Chipping

Field #65 Tensioned by:

- ☐ Untensioned
- ☐ Torquing
- ☐ Pulling

Field #66 Rock Bolt Accessories

- ☐ Channels
- ☐ Chain Line Fence
- ☐ Weld Wire Mesh

Shotcrete:

Field #67 Length of Support ______________ linear feet

Field #68 Thickness ______________ inches

Field #69 ☐ Full Circle

PERMANENT LINING

Field #70 Length of Permanent Lining ______________ linear feet

Reinforcing:

Field #71 Size of Bars ______________

Field #72 Spacing of Bars ______________ inches

Field #73 Number of Mats ______________

Concrete:

Field #74 Length of Concrete ______________ linear feet

Field #75 Type of Forms:

- ☐ Telescopic Full Circle
- ☐ Non-telescopic
- ☐ Telescopic Arch
- ☐ Bulkhead

Field #76 Power Sequence:

- ☐ Full Circles
- ☐ Curb-Invert Arch
- ☐ Invert Arch
- ☐ Curb Arch Invert
- ☐ Arch Invert

Field #77 Sequence:

- ☐ Advance
- ☐ Retreat

Field #78 Jumbos:

- ☐ Form
- ☐ Pouring
- ☐ Finishing

Field #79 Masonry Length____________ ____________ linear feet

Field #80 Steel or Iron Length____________________ linear feet

Field #81 Minimum Thickness of Lining______________ inches

UNEXPECTED PROBLEMS

Field #82 Loss of Heading______________________ times

Rock Falls:

Field #83 Number of Rock Falls____________________

Field #84 Size______________________________

Field #85 Injuries______________________________

Field #86 Deaths______________________________

LEGAL ACTIONS

Field #87 Number of Claims______________________

Field #88 Amount of Claims Requested_______________ dollars

Field #89 Amount of Claims Settled_______________ dollars

COSTS

Field #90 Bid Price_______________ dollars

Field #91 Actual Price_______________ dollars

TIME

Field #92 Completed_______________ days ahead of schedule

Field #93 Completed_______________ days behind schedule

Design Data Form

Field #1 Key Number____

Field #2 ☐ Plans Available

Microfilm number_________________________

SHAPE

Field #3 ☐ Circular ☐ Oval

☐ Rectangular ☐ Arched Roof

Field #4 Height_________________________ feet

Field #5 Width_________________________ feet

Field #6 Radius of Arch____________________ feet

LINING

Field #7 Total length of lining_______________________ linear feet

Unlined

Field #8 Total length_________________________ linear feet

Field #9 No support_________________________ linear feet

Field #10 Ribs______________________________ linear feet

Field #11 Rock Bolts_________________________ linear feet

Concrete

Field #12 Total Length_________________________ linear feet

Supported section:

Field #13 Minimum thickness________________ inches

Field #14 Maximum thickness________________ inches

	Unsupported section:	
Field #15	Minimum thickness ______	inches
Field #16	Maximum thickness ______	inches
	Reinforcement:	
Field #17	Size of bars ______	inches
Field #18	Spacing of bars ______	inches
Field #19	Number of mats ______	
	<u>Steel or Cast Iron</u>	
Field #20	Total length ______	linear feet
Field #21	Thickness ______	inches
	<u>Shotcrete</u>	
Field #22	Total length ______	linear feet
Field #23	Thickness ______	inches
	<u>Timber</u>	
Field #24	Total length ______	linear feet
Field #25	Thickness ______	inches
	<u>Brick or Masonry</u>	
Field #26	Total length ______	linear feet
Field #27	Thickness ______	inches
	Overburden height	
Field #28	Average height ______	feet
Field #29	Maximum height ______	feet
Field #30	Design load ______	psi
Field #31	Load derived from:	

☐ External hydro load ☐ Full rock load

☐ Triangle rock load ☐ Percent of full rock load

☐ Measurement

Field #32 ☐ Design computations available

Microfilm number ______________________

Field #33 Design method:

☐ Rock used as support member

☐ Thick walled cylinder

☐ Laminated cylinder

☐ Finite element

☐ Moment distribution

☐ Two-dimentional stress field

☐ Elastic theory for holes in stressed medium

☐ Time dependent stran considered

Field #34 Safety factor used ______________________

Field #35 Rock properties obtained from:

☐ Lab ☐ Field test

☐ Estimated ☐ Handbook

COST ESTIMATE

Field #36 Total ______________________ dollars

Field #37 Per linear foot ______________________ dollars

Field #38 Per cubic yard ______________________ dollars

Field #39 Lining cost per foot ______________________ dollars

SPECIFICATIONS

Field #40 ☐ Specs available

Microfilm number ______________________

Field #41 Liquidated damages ________________________________ dollars per day

Field #42 Payment

- ☐ Per foot
- ☐ Per yard
- ☐ Lump sum
- ☐ Cost plus
- ☐ Cost plus fixed fee

Field #43 Steel Support Payment:

- ☐ Per pound supplied
- ☐ Per pound installed
- ☐ Per pound supplied and installed
- ☐ Upset price

Field #44 ☐ Safety steel paid for

Field #45 Rock Bolt Payment:

- ☐ Each
- ☐ Per linear foot
- ☐ Lump sum

Field #46 ☐ Safety rock bolts paid for

Field #47 ☐ Contractor responsible for safety

Field #48 Passing Zones

- ☐ Not allowed
- ☐ Allowed outside design lines
- ☐ Allowed outside design lines but no pay

Field $49 Passing Zones Located:

- ☐ By engineer

Field #49 Passing Zones Located (cont):

- [ ] By contractor
- [ ] By contractor but approved by engineer

Field #50 Survey

- [ ] Engineer responsibility
- [ ] Contractor responsibility

Field #51 Feeler holes

Field #52 Excavation

- [ ] Tights allowed
- [ ] Overbreak paid for

Field #53 [ ] Excess water clause

Supports:

Steel sets:

Field #54 Size --- Minimum_______________ ______

Maximum______________________

Average______________________

Field #55 Spacing Minimum______________________ feet

Maximum______________________ feet

Average______________________ feet

Field #56 Design of steel:

- [ ] Proctor and White
- [ ] Rule of thumb or handbook

Field #56 Design of steel (cont):

☐ Past experience factor

☐ Educated guess

Field #57 Number of different weights of sets:

☐ One ☐ Two

☐ Three to five ☐ More than five

Field #58 Set Fabrication:

☐ One piece ☐ Two piece

☐ Three piece ☐ Wall plate

☐ Full circle ☐ Struts

Field #59 Set Installation:

☐ Overrun ☐ As designed

☐ Underrun ☐ Subject of claim

☐ Considered excessive by inspection

Rock Bolts:

Field #60 Rock Bolt Design Availalbe

Microfilm number____________________

Field #61 Diameter -- Minimum____________________

Maximum____________________

Average____________________

Spacing -- Minimum____________________ feet

Maximum____________________ feet

Average____________________ feet

Field #63	How Tensioned:	
	☐ By torque	
	☐ By pulling	
Field #64	Length____________________ feet	
Field #65	Tension____________________ psi	
Field #66	Exterior surface prepared by:	
	☐ Chipping	
	☐ Pad	
Field #67	Design:	
	☐ Rule of thumb	☐ Experience factor
	☐ Suspension	☐ Beam theory
	☐ Pattern bolts	☐ Grouted
Field #68	Installation:	
	☐ Overrun	☐ As designed
	☐ Underrun	☐ Subject of claim
	Retorquing:	
Field #69	Time limit____________________ days	
Field #70	Distance limit____________________ feet	
Field #71	☐ As directed	
Field #72	☐ Grouted	

General Data File Structure

Key Number	Project Name	Owner	Engineer	Contractor	Date Finished	Shape			
						Circular	Horse-shoe	Rectan-gular	Square
Field #1	Field #2	Field #3	Field #4	Field #5	Field #6	Field #7			

Shape			Length	Diameter or Span	Cost	Use				Location
Trapezoid	Arched Poof	Oval				Railroad	Highway	Water	Other	
Field #7			Field #8	Field #9	Field #10	Field #11				Field #12

Basic Computer Commands

LIBRARY RELATED COMMANDS

CATALOG
Prints the list of programs and files saved in a library

CATALOG $\left[\begin{Bmatrix} * \\ ** \\ *** \end{Bmatrix} \right]$

CATALOG ALL
Prints the list of programs and files saved in the user's private library along with descriptive information

CATALOG ALL

SAVE
Saves program work area in a user's private or *shared library

SAVE (file name)

REMOVE
Deletes a user's private or *shared library file from the library

REMOVE (file name)

PROTECT
Protects a user's private or *shared library file from destruction

PROTECT (file name)

UNPROTECT
Removes protected status of a user's private or *shared library file

UNPROTECT (file name)

PROGRAM EXECUTION COMMANDS

RUN
Starts execution of program

$$\underline{\text{RUN}}\left[\begin{Bmatrix}\text{file name (,start line no.)}\\ \text{start line no.}\end{Bmatrix}\right]$$

RUN**ANNUIT,50

CONTINUE
Resumes execution of program at current execution point without reset of execution status

CONTINUE

EXECUTE
Executes a single program statement

EXECUTE (file no.)

Display Command
Prints value of a simple variable or array element at terminal. Subscripts must be integer constants.

variable name

A(1,2)

STATUS
Prints current execution status

STATUS

RESET
Changes execution state of program

RESET (ALL)

PROGRAMMER'S WORK AREA COMMANDS

CLEAR
Clears all or selected statements from program work area

$$\underline{\text{CLE}}\text{AR} \left[\begin{Bmatrix}\text{line no.}\\ \text{line no. range}\end{Bmatrix}, \ldots, \begin{Bmatrix}\text{line no.}\\ \text{line no. range}\end{Bmatrix} \right]$$

CLEAR 10-30,50,110-170,320

LOAD
Loads the program work area with files saved in a library

$$\underline{\text{LOA}}\text{D} \left[\text{(file name)}, \ldots, \text{(file name)} \right]$$

LOAD PROG, SUB1,*SUB2

MERGE
Merges a saved file with the current content of the program area

$$\underline{\text{MER}}\text{GE} \left[\text{file name} \quad \text{(,line no.)} \right]$$

MERGE PROGA, 1000

LIST
Prints at the terminal all or selected statements of the program work area. Line numbers are not printed with the NN option.

$$\underline{\text{LIST}}\ (\underline{\text{NN}}) \left[\begin{Bmatrix}\text{line no.}\\ \text{line no. range}\end{Bmatrix}, \ldots, \begin{Bmatrix}\text{line no.}\\ \text{line no. range}\end{Bmatrix} \right]$$

LIST 100-150,210,300-

EDIT
Edits all or selected statements of the program work area

$$\underline{\text{EDIT}}\ \underline{\text{LIST}}\ \left[\begin{Bmatrix}\text{line no.}\\ \text{line no. range}\end{Bmatrix}, \ldots, \begin{Bmatrix}\text{line no.}\\ \text{line no. range}\end{Bmatrix}\right]$$

$$;\begin{bmatrix}\text{replaced}\\ \text{string con.}\end{bmatrix};\begin{bmatrix}\text{replacement}\\ \text{string con.}\end{bmatrix}$$

EDIT 50-100,150,WXYZ,"ABC"

RENUMBER
Renumbers lines of the program work area.

Values of 100 and 10 are assumed for new start line no. and increment if unspecified.

$$\underline{\text{REN}}\text{UMBER}\ \left[\text{start line no.}\ \left[\text{, new start line no. (, increment)}\right]\right]$$

Renumber 325,1000,20

CHECK
Checks statements in the program work area for errors
$\underline{\text{CHECK}}$

PUNCH
Punches on paper tape at the terminal all or selected statements of the program work area

$$\underline{\text{PUNCH}}\ \left[\begin{Bmatrix}\text{line no.}\\ \text{line no. range}\end{Bmatrix}, \ldots, \begin{Bmatrix}\text{line no.}\\ \text{line no. range}\end{Bmatrix}\right]$$

PUNCH 50,100-200,1010-

NAME
Names the program work area
$\underline{\text{NAME}}$ (file name)

TAPE
Sets input mode to paper tape
<u>TAP</u>E

INFO
Prints information concerning program in work area
<u>INF</u>O

List of Available Variables and Arrays

VARIABLE NAME	DESCRIPTION
A$ (array)	Contains the values of all the alphabetic field of the current record. If the i^{th} field of the record is alphabetic, it is stored in A$(i).
A (array)	Contains the values of all the numeric fields of the current record. If the i^{th} field of the record is numeric, it is stored in A(1).
B (array)	Contains codes indicating the numeric and alphabetic characteristics of each field of the record (i.e., 0 for numeric and and 1 for alphabetic). B(1) refers to the i^{th} field of the record.
C (array)	Contains the numbers of the fields on which totals are to be taken. For example, C(1) contains the field number for the first requested field total.
D (array)	Contains the accumulated field totals. The first element in the array, D(1), contains the totals for the first field listed in the field totals specification, the second element in the array, D(2), contains the totals for the second field listed in the field totals specification. At lines 6000-6999, this array contains subtotals, updated with the current selected record, and, at lines 7000-7999, it contains final totals, since all records have been read

VARIABLE NAME	DESCRIPTION
C1 (variable)	Contains the number of fields in a record.
C2 (variable)	Contains the number of fields to be totaled.
T2 (variable)	Contains a count on the number of records read. At lines 6000-6999, T2 has been updated by the currently read record and contains a subtotal. At lines 7000-7999, T2 contains a final count on the number of records read.
T4 (variable)	Contains a count on the number of records selected. At lines 6000-6999, T4 has been updated by the currently selected record and contains a subtotal. At lines 7000-7999 ,it contains a final count on the number of records selected. If the record selection is such that there is no specified record selection (all records selected), then T2 contains a count on both records read and records selected. T4 is not updated and should not be used.
Q1 (variable)	User read switch. Must be used only at lines 4000-4999.

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
BNR	Cape Horn #1	Arched Roof	2,369'	Basalt	Full Face	Timber
BNR	Cape Horn #2	Arched Roof	122'	Basalt	Full Face	Concrete
BNR	Cape Horn #3	Arched Roof	416'	Basalt	Full Face	Concrete
BNR	Cape Horn #4	Arched Roof	267'	Basalt	Full Face	Concrete
BNR	Cape Horn #5	Arched Roof	395'	Basalt	Full Face	Concrete
BNR	Cape Horn #6	Arched Roof	657'	Basalt	Full Face	Concrete
BNR	Cape Horn #7	Arched Roof	966'	Basalt	Full Face	Concrete
BNR	Cape Horn #8	Arched Roof	755'	Basalt	Full Face	Concrete
BNR	Cape Horn #9	Arched Roof	392'	Basalt	Full Face	Concrete
BNR	Cape Horn #10	Arched Roof	576'	Basalt	Full Face	Concrete
BNR	Cape Horn #11	Arched Roof	269'	Basalt	Full Face	Timber
BNR	Cape Horn #12	Arched Roof	385'	Basalt	Full Face	Concrete
BNR	Cape Horn #14	Arched Roof	203'	Basalt	Full Face	Timber
BNR	Cape Horn #16	Arched Roof	2,494'	Basalt	Full Face	Timber

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
BNR	Cape Horn #17	Arched Roof	2,220'	Basalt	Full Face	Concrete
BNR	Cape Horn #18	Arched Roof	369'	Basalt	Full Face	Concrete
BNR	Fort Wright #19	Arched Roof	2,134'	Volcanics	Full Face	Concrete
BNR	O T Ry #1	Arched Roof	814'	Volcanics	Full Face	Concrete
BNR	O T Ry #2	Arched Roof	810'	Volcanics	Full Face	Timber
BNR	O T Ry #3	Arched Roof	480'	Volcanics	Full Face	Concrete
BNR	O T Ry #4	Arched Roof	384'	Volcanics	Full Face	Concrete
BNR	Gateway #5	Arched Roof	542'	Volcanics	Full Face	Timber
BNR	Mayger #3	Arched Roof	175'	Volcanics	Full Face	Timber
BNR	Cornelius	Arched Roof	4,111'	Volcanics-Sedimentary	Full Face	Concrete-Timber
BNR	Cascade	Arched Roof	41,152'	Andesite - Sediment	Full Face	Concrete
BNR	Everett #15	Arched Roof	2,440'	Glacial debris	Full Face	Concrete

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
BNR	Oroville #7	Arched Roof	1,761'	Metamorphics	Full Face	Timber
BNR	Samish #18	Arched Roof	1,113'	Metamorphics	Full Face	Concrete
BNR	Seattle #17	Arched Roof	5,142'	Glacial debris	Full Face	Concrete
BNR	Winston #14	Arched Roof	4,059'	Volcanics	Full Face	Concrete
BNR	Stampede #1	Arched Roof	9,834'	Andesite	Full Face	Concrete
BNR	Stampede #4	Arched Roof	649'	Sediments	Full Face	Concrete
BNR	Ostrander	Arched Roof	1,165'	Volcanics	Full Face	Concrete
BNR	Nelson-Bennett	Arched Roof	4,391'	Glacial debris	Full Face	Concrete
BNR	Ruston	Arched Roof	323'	Glacial debris	Full Face	Concrete
CE-Portland	Blue River Dam	Circular	1,795'	Altered tuffs-Intrusives	Top head-bench	Ribs-Rock bolt
CE-Portland	Cougar Dam	Arched Roof	1,834'	Basalt lava-tuffs	Full Face	Rock bolts
CE-Portland	Cougar Dam	Arched Roof	1,043'	Basalt lava-tuffs	Pilot-Full Face	Rock bolts

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
CE-Portland	Cougar Dam	Circular	963'	Basalt lava	Full Face	Rock Bolts
CE-Portland	Cougar Dam	Arched Roof	630'	Basalt lava-Tuffs	Full Face	Rock Bolts
CE-Portland	Green Peter Dam	Arched Roof	1,050'	Lavas-Tuffs	Top head-bench	Ribs-Bolts
CE-Portland	Big Cliff Dam	Arched Roof	631'	Meta Volcanics	Full Face	No Supports
CE-Portland	Detroit Dam	Horseshoe	1,364'	Meta Volcanics	Full Face	No Supports
CE-Seattle	Eagle Gorge Outlet	Arched Roof	-----	-------	-----	------
CE-Seattle	Howard Hanson Dam	Horseshoe	900'	Lava or Volcanics	Full Face	Ribs
CE-Seattle	Mud Mountain	Circular	1,991'	Volcanic agglom	Full Face	Ribs-Concrete
CE-Seattle	Mud Mountain	Arched Roof	1,800'	Volcanic agglom	Full Face	Ribs-Concrete
CE-W W	Dworshak Dam	Horseshoe	1,722'	Gneiss,massive to schistose	Full Face	Rock bolts-Rib sections

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
CE-W W	Lucky Peak Dam	Circular	1,161'	Basalt lava	Full Face	182 Ribs
EWEB	Carmen Smith	Horseshoe	7,284'	Lava or Basalt	Full Face	Ribs-concrete, unsupported sections
EWEB	Carmen Smith Div.	Arched Roof	11,381'	Basalt	Full Face	Ribs, rock bolts
OSH	Knowles Creek	Arched Roof	1,430'	Lava or tuffs	Full Face	Concrete
OSH	Sunset	Arched Roof	800'	Marine-Sedimentary rocks	Full Face	Timber sets-lagging
OSH	Tooth Rock	Arched Roof	837'	Basalt lava	Full Face	Concrete
OSH	Elk Creek	Arched Roof	1,090'	Marine-Sedimentary Rocks	Full Face	Concrete
OSH	Cape Creek	Arched Roof	714'	Basalt lava	Full Face	Concrete
OSH	Arch Cape	Arched Roof	1,228'	Basalt lava	Full Face	Concrete
OSH	Vista Ridge West	Arched Roof	1,001'	Basalt lava	Side drift-top head-bench	Steel Ribs-Concrete

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
OSH	Vista Ridge East	Arched Roof	1,048'	Basalt lava	Side drift-top head-bench	Steel ribs-Concrete
PP and L	J.C. Boyle	Horseshoe	1,662'	Altered Volcanics	Full Face	Steel
PP and L	Toketee	Horseshoe	5,400'	Basalt-Tuffs	Full Face	Timber
PP and L	Swift Tunnel	Horseshoe	-----	Basalt-Tuffs	Full Face	Unsupported
PGE	Faraday	Horseshoe	2,426'	Tuffs	Full Face	Unsupported
PGE	Oak Grove #1	Circular	170'	Tuffs	Full Face	Concrete
PGE	Oak Grove #2	Circular	250'	Tuffs	Full Face	Concrete
PGE	Oak Grove #3	Circular	1,300'	Tuffs	Full Face	Timber
PGE	Round Butte	Circular	1,520'	Basalt-tuffs	Full Face	Concrete
PGE	Round Butte	Circular	2,093'	Basalt-tuffs	Full Face	Concrete
PGE	Round Butte	Circular	390'	Basalt-tuffs	Full Face	Concrete

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
PGE	Round Butte, LL Grout	Rectangular	797'	Basalt	Full Face	Unsupported
PGE	Round Butte, LL Access	Rectangular	963'	Basalt	Full Face	Unsupported
PGE	Round Butte, UL Grout	Rectangular	280'	Basalt	Full Face	Unsupported
PGE	Round Butte, UL Access	Rectangular	413'	Basalt	Full Face	Unsupported
PGE	Round Butte, LR Grout	Rectangular	600'	Basalt	Full Face	Unsupported
PGE	Round Butte, LR Access	Rectangular	972'	Basalt	Full Face	Unsupported
PGE	Round Butte, UR Access	Rectangular	438'	Basalt	Full Face	Unsupported
PGE	Round Butte, UR Grout	Rectangular	167'	Basalt	Full Face	Unsupported

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
PGE	Bull Run Tunnel #10	Horseshoe	457'	Basalt-Tuffs	Full Face	Timber
PGE	Bull Run Tunnel #1	Horseshoe	4,702'	Basalt Tuffs	Full Face	Timber-Un-supported
PGE	Bull Run Tunnel #2-3	Horseshoe	1,550'	Basalt-Tuffs	Full Face	Timber-Un-supported
PGE	Bull Run Tunnel #4	Horseshoe	2,180'	Basalt-Tuffs	Full Face	Timber-Un-supported
PWB	Bull Run Dam #2	Circular	1,000'	Slide Rubble	Full Face	Ribs-Concrete
PWB	Bull Run Left Abt	Circular	1,700'	Slide Rubble	Full Face	Ribs-Concrete
SPT	Abernathy	Arched Roof	698'	Lavas-Tuffs	Full Face	Timber
SPT	Cascade Summit	Arched Roof	3,655'	Lavas-Tuffs	Full Face	Timber - Un-supported
SPT	Cruzatte	Arched Roof	964'	Lavas-Tuffs	Full Face	Unsupported
SPT	Cruzatte	Arched Roof	566'	Lavas-Tuffs	Full Face	Timber
SPT	Cruzatte	Arched Roof	3,164'	Lavas-Tuffs	Full Face	Timber-Un-supported

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
SPT	Cruzatte	Arched Roof	671'	Lavas-Tuffs	Full Face	Timber-Un-supported
SPT	Cruzatte	Arched Roof	1,144'	Lavas-Tuffs	Full Face	Timber - Unsupported
SPT	Cruzatte	Arched Roof	466'	Lavas-Tuffs	Full Face	Timber - Unsupported
SPT	Fields	Arched Roof	150'	Lavas-Tuffs	Full Face	Timber - Unsupported
SPT	Fields	Arched Roof	2,213'	Lavas-Tuffs	Full Face	Unsupported
SPT	Fields	Arched Roof	267'	Lavas-Tuffs	Full Face	Unsupported
SPT	Frazier	Arched Roof	779'	Lavas-Tuffs	Full Face	Timber - Unsupported
SPT	Frazier	Arched Roof	359'	Lavas-Tuffs	Full Face	Timber - Unsupported
SPT	Frazier	Arched Roof	875'	Lavas-Tuffs	Full Face	Unsupported
SPT	Frazier	Arched Roof	2,121'	Lavas-Tuffs	Full Face	Steel sets - unlined

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
SPT	Lookout	Arched Roof	654'	Lavas-Tuffs	Full Face	Timber - Unsupported
SPT	Lookout	Arched Roof	393'	Lavas-Tuffs	Full Face	Steel sets-Unlined
SPT	McCredie Springs	Arched Roof	460'	Lavas-Tuffs	Full Face	Timber - Unsupported
SPT	Westfir	Arched Roof	1,999'	Lavas-Tuffs	Full Face	Timber - Unsupported
SPT	Wicopee	Arched Roof	639'	Lavas-Tuffs	Full Face	Unsupported
SPT	Wicopee	Arched Roof	363'	Lavas-Tuffs	Full Face	Timber - Unsupported
SPT	Wicopee	Arched Roof	436'	Lavas-Tuffs	Full Face	Unsupported
SPT	Canary	Arched Roof	624'	Marine Sedimentary rocks	Full Face	Timber - Concrete
SPT	Cushman	Arched Roof	2,142'	Marine Sedimentary rocks	Full Face	Timber
SPT	Richardson	Arched Roof	473'	Marine Sedimentary rocks	Full Face	Timber

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
SPT	Kroll	Arched Roof	1,200'	Marine Sedimentary rocks	Full Face	Timber - Unsupported
SPT	Kroll	Arched Roof	1,556'	Marine Sedimentary rocks	Full Face	Timber
SPT	Reedsport	Arched Roof	4,183'	Marine Sedimentary rocks	Full Face	Timber
SPT	Lakeside	Arched Roof	870'	Marine Sedimentary rocks	Full Face	Timber
SPT	Lakeside	Arched Roof	475'	Marine Sedimentary rocks	Full Face	Timber - Unsupported
SPT	Vaughn	Arched Roof	2,489'	Marine Sedimentary rocks	Full Face	Timber-Unsupported
SPT	Cornutt	Arched Roof	264'	Hard mesozoic Sedimentary rocks	Full Face	Unsupported
SPT	Glendale	Arched Roof	423'	Hard mesozoic Sedimentary rocks	Full Face	Timber - Unsupported

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
SPT	Glendale	Arched Roof	433'	Hard mesozoic Sedimentary rocks	Full Face	Unsupported
SPT	Glendale	Arched Roof	332'	Hard mesozoic Sedimentary rocks	Full Face	Timber
SPT	Glendale	Arched Roof	341'	Hard mesozoic Sedimentary rocks	Full Face	Timber
SPT	Glendale	Arched Roof	517'	Hard mesozoic Sedimentary rocks	Full Face	Timber
SPT	Glendale	Arched Roof	128'	Hard mesozoic Sedimentary rocks	Full Face	Timber
SPT	Hugo	Arched Roof	2,105'	Hard mesozoic Sedimentary rocks	Full Face	Timber
SPT	Wolf Creek	Arched Roof	2,811'	Hard mesozoic Sedimentary rocks	Full Face	Timber - Unsupported

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
SPT	Siskiyou	Arched Roof	3,107'	Non-marine Sedimentary rocks	Full Face	Timber
SPT	Siskiyou	Arched Roof	1,192'	Non-marine Sedimentary rocks	Full Face	Timber - Unsupported
SPT	Siskiyou	Arched Roof	258'	Granite	Full Face	Unsupported
SPT	Siskiyou	Arched Roof	414'	Altered Vol-canic rocks	Full Face	Unsupported
SPT	Cochran	Arched Roof	412	Altered Vol-canic rocks	Full Face	Timber - Unsupported
SPT	Enright	Arched Roof	240'	Altered Vol-canic rocks	Full Face	Timber - Unsupported
SPT	Enright	Arched Roof	292'	Altered Vol-canic rocks	Full Face	Timber - Unsupported
SPT	Enright	Arched	262'	Altered Vol-canic rocks	Full Face	Timber
SPT	Enright	Arched Roof	500'	Altered Vol-canic rocks	Full Face	Timber

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
SPT	Enright	Arched Roof	303'	Altered Volcanic rocks	Full Face	Unlined
SPT	Enright	Arched Roof	251'	Altered Volcanic rocks	Full Face	Unsupported
SPT	Enright	Arched Roof	179'	Altered Volcanic rocks	Full Face	Timber - Unsupported
SPT	Timber	Arched Roof	1,417'	Marine Sedimentary rocks	Full Face	Timber - Concrete
SPT	Eddyville	Arched Roof	682'	Marine Sedimentary rocks	Full Face	Timber - Concrete
SPT	Wilsonia	Arched Roof	1,396'	Basalt Lava	Full Face	Timber - Concrete
Tacoma PUD	Mayfield	Horseshoe	830'	Basalt-Tuffs	Full Face-Top head-bench	Steel Ribs - Rock bolts
Tacoma PUD	Mayfield	Horseshoe	548'	Basalt-Tuffs	Full Face	Steel Ribs
Tacoma PUD	Mossy Rock	Arched Roof	1,794'	Basalt-Tuffs	Full Face	Steel Ribs

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
Tacoma PUD	Mossy Rock Div #2	Arched Roof	1,488	Basalt-Tuffs	Full Face	Steel Ribs
Tacoma PUD	La Grande Dam	Circular	6,236'	Basalt-Tuffs-Glacial debris	Full Face	Timber-Steel-Unsupported
Tacoma PUD	Cushman	Circular	-----	Anesite flows-breccia	Full Face	Timber - Unsupported
Tacoma PUD	Cushman	Horseshoe	-----	Anesite flows-breccia	Full Face	Timber - Unsupported
UPR	Port-Hunnington	Arched Roof	654'	Basalt lava	Full Face	Concrete
UPR	Port-Hunnington	Arched Roof	635'	Basalt lava	Full Face	Concrete
UPR	Port-Hunnington	Arched Roof	478'	Basalt lava	Full Face	Concrete
UPR	Port-Hunnington	Arched Roof	610'	Basalt lava	Full Face	Concrete
UPR	Port-Hunnington	Arched Roof	518'	Schist	Full Face	Timber - Concrete
UPR	Port-Seattle	Arched Roof	5,436'	Compact sand-gravel	Shield, Cut-Cover	Timber sets-lagging-reinforced concrete

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
UPR	Port-Seattle	Arched Roof	623'	Basalt lava	Full Face	Timber
UPR	Port-Spokane	Arched Roof	994'	Basalt lava	Full Face	Timber
UPR	Port-Spokane	Arched Roof	1,760'	Basalt lava	Full Face	Timber
UPR	Port-Spokane	Arched Roof	494'	Basalt lava	Full Face	Timber
UPR	Port-Spokane	Arched Roof	958'	Basalt lava	Full Face	Timber
UPR	Port-Spokane	Arched Roof	593'	Basalt lava	Full Face	Timber
UPR	Port-Spokane	Arched Roof	909'	Basalt lava	Full Face	Timber
UPR	Port-Spokane	Arched Roof	667'	Basalt lava	Full Face	Unlined
UPR	Port-Spokane	Arched Roof	426'	Basalt lava	Full Face	Timber
UPR	Olympia Branch	Arched Roof	108'	Basalt-andesite	Full Face	Unlined
UPR	Olympia Branch	Arched Roof	665'	Basalt - andesite	Full Face	Unlined
UPR	Oregon E. Branch	Arched Roof	2,537'	Basalt	Full Face	Unsupported
UPR	Oregon E. Branch	Arched Roof	138'	Basalt	Full Face	Unsupported

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
WSH	2/108 Tunnel	Arch	184'	Granite	Full Face	Concrete
WSH	12/308 Rimrock Tunnel	Arch	577'	Volcanics	Full Face	Concrete
WSH	14/128 Tunnel #1	Arch	130'	Basalt	Full Face	Concrete
WSH	12/129 Tunnel #2	Arch	408'	Basalt	Full Face	Concrete
WSH	14/130 Tunnel #3	Arch	257'	Basalt	Full Face	Concrete
WSH	14/133 Tunnel #4	Arch	261'	Basalt	Full Face	Concrete
WSH	14/134 Tunnel #5	Arch	212'	Basalt	Full Face	Concrete
WSH	14/206 Bingen Tunnel	Arch	118'	Basalt	Full Face	Concrete
WSH	14/125	Arch	389'	Basalt	Full Face	Concrete
WSH	14/216	Arch	233'	Basalt	Full Face	Concrete
WSH	20/108	Arch	603'	Granite	Full Face	Steel sets - concrete
WSH	20/111	Arch	88'	Granite	Full Face	Concrete
WSH	20/113N	Arch	361'	Granite	Full Face	Concrete

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
WSH	101/3 Fort Columbia	Arch	800'	Marine Sediments	Full Face	Timber sets-lagging
WSH	123/106	Arch	510'	Volcanics	Full Face	Concrete
WSH	97/24 Mt. Baker Ridge	Arch	1,466'	Continental sediments	Full Face	Concrete
WSH	97/359 Knapps Hill	Arch	740'	Volcanics	Full Face	Concrete
BR-Boise	Black Canyon #1	Horseshoe	825'		Full Face	Concrete
BR-Boise	Black Canyon #2	Horseshoe	475'		Full Face	Concrete
BR-Boise	Black Canyon #2A	Horseshoe	422'		Full Face	Concrete
BR-Boise	Black Canyon #3	Horseshoe	1,375'		Full Face	Concrete
BR-Boise	Black Canyon #4	Horseshoe	1,270		Full Face	Concrete
BR-Boise	Black Canyon #5	Horseshoe	640'		Full Face	Concrete
BR-Boise	Black Canyon #6	Horseshoe	870'		Full Face	Concrete
BR-Boise	Black Canyon #8	Horseshoe	1,630'		Full Face	Concrete
BR-Boise	Black Canyon #9	Horseshoe	3,170'		Full Face	Concrete

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
BR-Boise	Columbia Basin	Horseshoe	10,037'	Basalt-Tuffs	Full Face	Steel
BR-Boise	Columbia Basin	Horseshoe	9,280'	Basalt-Tuffs	Full Face	Steel
BR-Boise	Columbia Basin	Horseshoe	2,560'	Granite	Full Face	Unsupported
BR-Boise	Deschutes	Horseshoe	3,443'	Basalt-Tuffs	Full Face	Concrete
BR-Boise	Deschutes	Horseshoe	3,361'	Basalt-Tuffs	Full Face	Concrete
BR-Boise	Owyhee	Horseshoe	440'	Granite	Full Face	Concrete
BR-Boise	Owyhee	Horseshoe	350'	Granite	Full Face	Concrete
BR-Boise	Owyhee	Horseshoe	18,723'		Full Face	Concrete
BR-Boise	Owyhee	Horseshoe	1,354'	Basalt	Full Face	Concrete
BR-Boise	Owyhee	Horseshoe	1,990'	Basalt	Full Face	Concrete
BR-Boise	Owyhee	Horseshoe	21,948'	Volcanics	Full Face	Concrete
BR-Boise	Owyhee	Horseshoe	1,040'	Volcanics	Full Face	Concrete
BR-Boise	Owyhee	Horseshoe	4,325'	Volcanics	Full Face	Concrete

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
BR-Boise	Rogue River Basin	Circular	2,100'	Volcanics	Full Face	Concrete
BR-Boise	Rogue River Basin	Horseshoe	3,553'	Volcanics	Full Face	Concrete
BR-Boise	Rogue River Basin	Circular	4,833'	Volcanics	Full Face	Concrete
BR-Boise	Vale Tunnel #1	Horseshoe	2,150'	Sedimentary	Full Face	Concrete
BR-Boise	Vale Tunnel #2	Horseshoe	5,007'	Sedimentary	Full Face	Concrete
BR-Boise	Vale Tunnel #3	Horseshoe	1,312'	Sedimentary	Full Face	Concrete
BR-Boise	Vale Tunnel #4	Horseshoe	500'	Sedimentary	Full Face	Concrete
BR-Boise	Vale Tunnel #5	Horseshoe	286'	Sedimentary	Full Face	Concrete
BR-Boise	Yakima Project	Horseshoe	179'	Volcanics	Full Face	Concrete
BR-Boise	Yakima Project	Horseshoe	305'	Basalts-Tuffs	Full Face	Concrete
BR-Boise	Yakima Project	Circular	3,640'	Volcanics	Full Face	Concrete
BR-Boise	Yakima Project	Horseshoe	1,686'	Basalts-Tuffs	Full Face	Concrete
BR-Boise	Yakima Project	Horseshoe	1,025'	Basalts-Tuffs	Full Face	Concrete
BR-Boise	Yakima Project	Horseshoe	2,276'	Basalts-Tuffs	Full Face	Concret

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
BR-Boise	Yakima Project	Horseshoe	482'	Basalts-Tuffs	Full Face	Concrete
BR-Boise	Yakima Project	Horseshoe	3,470'	Volcanics	Full Face	Concrete
BR-Boise	Yakima Project	Horseshoe	2,000'	Volcanics	Full Face	Concrete
BR-Boise	Yakima Project	Horseshoe	1,390'	Volcanics	Full Face	Concrete
BR-Boise	Yakima Project	Horseshoe	8,231'	Volcanics	Full Face	Concrete
BR-Boise	Yakima Project	Horseshoe	9,588'	Basalt-Tuffs	Full Face	Concrete
BR-Boise	Yakima Project	Horseshoe	3,988'	Basalt-Tuffs	Full Face	Concrete
BR-Boise	Yakima Project	Horseshoe	755'	Basalt-Tuffs	Full Face	Concrete
BR-Boise	Yakima Project	Horseshoe	1,475'	Basalt-Tuffs	Full Face	Concrete
BR-Boise	Prineville Dam	Circular	529'	Basalt lava	Full Face	Concrete
BR-Boise	Prineville Dam	Arched Roof	331'	Basalt lava	Full Face	Concrete
BR-Boise	Klamath Project	Horseshoe	3,300'	Lava-Tuffs	Full Face	Unlined
CMSP	Blue Slide	Arched Roof	1,093'		Full Face	Timber
CMSP	Johnson Creek #45	Arched Roof	1,973		Full Face	Timber

GENERAL TUNNEL DATA

Organization	Project	Cross Section	Length	Rock Types	Tunnel Method	Supports Used
CMSP	Easton	Arched Roof	203'		Full Face	Concrete
CMSP	Horlick #1	Arched Roof	496'		Full Face	Unlined
CMSP	Horlick #2	Arched Roof	1,239'		Full Face	Concrete
CMSP	Tancum	Arched Roof	496'		Full Face	Concrete
CMSP	Snoqualmie	Arched Roof	11,890'		Full Face	Concrete
CMSP	Vail	Arched Roof	810'		Full Face	Timber
CMSP	Wolf Creek	Arched Roof	90'		Full Face	Timber
CMSP	Palisades	Arched Roof	756'		Full Face	Unlined
CMSP	Rocklake #43	Arched Roof	756'		Full Face	Unlined
CMSP	Watts #41	Arched Roof	2,559'		Full Face	Concrete
CMSP	.2 M. E. Spokane	Arched Roof	863'		Full Face	Concrete
CMSP	Whittler	Arched Roof	528'		Full Face	Concrete

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A study was made to determine none	U. S. Bureau of Mines Department of the Interior

13. ABSTRACT

Under the ARPA Contract No. HO210035, Foundation Sciences, Inc. determined the feasibility of collecting information on the construction of underground works, especially those of the last twenty years. The gathering and quantitizing of this type of information was performed for the Oregon and Washington areas as a pilot project. During the first phase, data was collected

The first phase of the study involved the collection of as much of the data as available about the geology, design, construction and performance of existing underground rock excavations and the tabulation of this knowledge for a data bank. was tabulated in a To date, all information contained in the "general data" forms for 256 projects have been entered into the computer.

The second phase of the study involved the evaluation of data available with special reference to those items of design and construction affecting supports. Two projects were selected for intensive study. Using the advantage of hindsight, an attempt was made to obtain an overview of each project and see how the separate phases of exploration, design, construction and inspection blended in order to form a finished project. A

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KLAMATH PROJECT
SP TUNNEL 17
SP TUNNEL 18
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GREEN PETER DAM
BLUE RIVER DAM
SP TUNNEL 1
SP TUNNEL 8
GREEN SPRINGS TUNNEL

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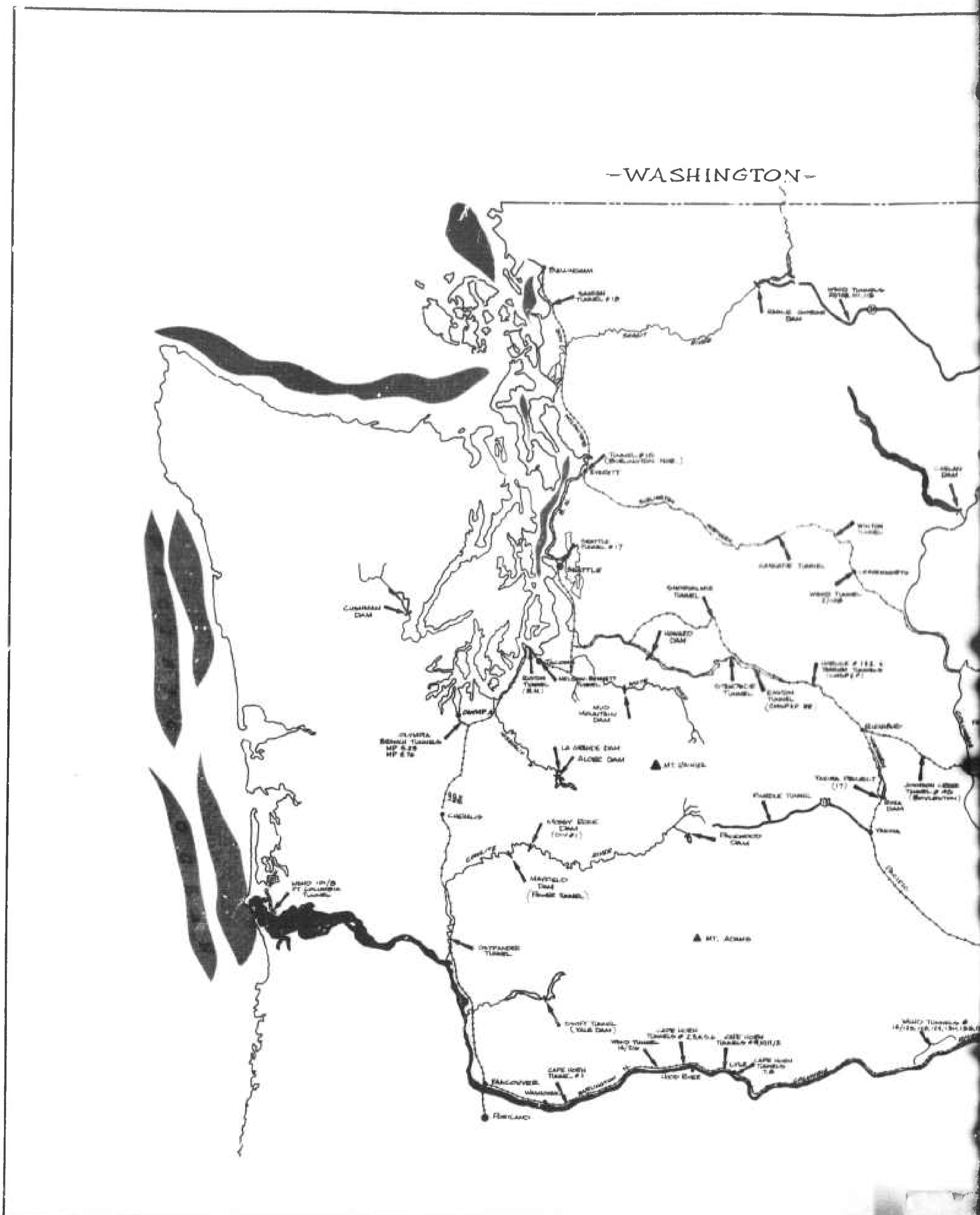
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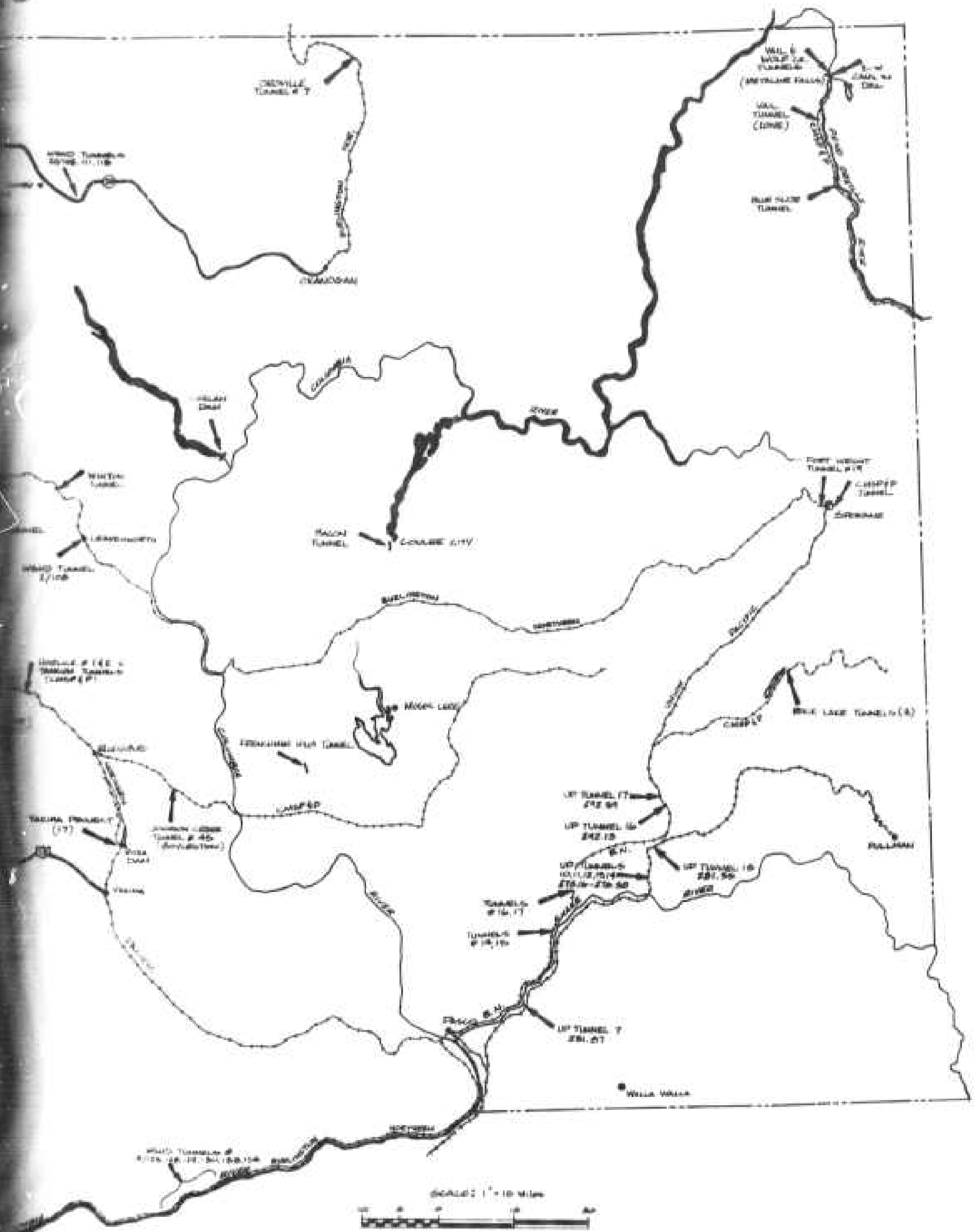

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